UNITED STATES

AMLR ANTARCTIC MARINE LIVING RESOURCES PROGRAM

AMLR 2007/2008 FIELD SEASON REPORT

Objectives, Accomplishments and Tentative Conclusions

Edited by
Amy M. Van Cise

October 2008

NOAA-TM-NMFS-SWFSC-427

Southwest Fisheries Science Center
Antarctic Ecosystem Research Group

The National Oceanic and Atmospheric Administration (NOAA), organized in 1970, has evolved into an agency which establishes national policies and manages and conserves our oceanic, coastal, and atmospheric resources. An organizational element within NOAA, the Office of Fisheries is responsible for fisheries policy and the direction of the National Marine Fisheries Service (NMFS).

In addition to its formal publications, the NMFS uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series, however, reflect sound professional work and may be referenced in the formal scientific and technical literature.

The U.S. Antarctic Marine Living Resources (AMLR) program provides information needed to formulate U.S. policy on the conservation and international management of resources living in the oceans surrounding Antarctica. The program advises the U.S. delegation to the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), part of the Antarctic treaty system. The U.S. AMLR program is managed by the Antarctic Ecosystem Research Group located at the Southwest Fisheries Science Center in La Jolla.

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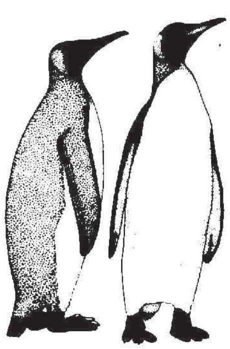

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Background

The 2007/08 U.S. Antarctic Marine Living Resources (U.S. AMLR) field season continues a long-term series of studies of the Antarctic ecosystem, designed to provide scientific support for the conservation and management of Antarctic marine fisheries as outlined by the international Committee for the Conservation of Antarctic Marine Living Resources (CCAMLR).

The research completed in the field is used to describe the Antarctic ecosystem as a function of the relationships between Antarctic krill (*Euphausia superba*), their predators and the physical and biological oceanographic conditions of Antarctic waters. Two working hypotheses have been proposed based on the data collected: 1) krill predators respond to changes in the availability of their food source, and 2) the distribution of krill is affected by both physical and biological aspects of their habitat.

Since the conception of the U.S. AMLR research program, annual field studies have been conducted in the vicinity of the South Shetland Islands (Figure 1), which are located to the north of the Antarctic Peninsula. Historically, these field studies include land-based observation of pinniped and seabird ecology from two stations, located at Cape Shirreff on Livingston Island and Admiralty Bay (Copacabana) on King George Island (Figure 1), and two identical pelagic surveys of the waters surrounding the South Shetland Islands (Figure 2), completed in January and again in February. In the austral summer of 2007/2008 the U.S. AMLR program augmented its traditional study area to include an additional pelagic survey in the area of the South Orkney Islands (Figure 3). This opportunity for additional study represents part of the US International Polar Year contribution, as part of the Census of Antarctic Marine Life (CAML) project.

This is the 20^{th} issue in the series of U.S. AMLR field season reports, documenting the 22^{nd} year of Antarctic research.

Summary of 2008 Results

Shipboard mapping of the waters around the South Shetland Islands indicates that several water masses converge in the area, forming a hydrographic front along the shelf break north of the archipelago. This front is associated with high densities of phytoplankton and Antarctic krill, although there is great variability in the seasonal presence and reproductive success of krill, which is strongly correlated with multi-year trends in the physical environment.

During the 2007/08 U.S. AMLR season, net based estimates of krill abundance increased while acoustically based estimates of krill biomass decreased, possibly indicating a strong recruitment from the 2006/07 austral summer. Observed penguin populations declined compared to the 2006/07 breeding season; however, chick health was similar to previous years. Antarctic fur seals were observed foraging at distances farther from their rookery sites than normal. Their over-winter survival during 2007 was below average, and reproductive success during the 2007/08 breeding season was average, while Leopard seal predation was higher than most years, associated with an overall decline in the fur seal population.

Oceanographic data:

Air temperature averaged 2.3°C in January (Survey A) and 2.1°C in February (Survey D). Wind direction in January was predominately west to northwest with wind speeds averaging 19 knots. During February the average wind speed was lower, averaging 17.8 knots, with wind direction still mainly from the west and northwest. Cloud cover was less in January than February. The position of the polar frontal zone, identified by pronounced sea surface temperature and salinity change, varied within the range of 57-58° S latitude over the course of the study.

As in previous years, an attempt was made to group stations with similar temperature and salinity profiles into five Water Zones. The tentative Water Zone classifications were sometimes prone to ambiguity, particularly in the coastal regions around King George & Livingston Islands and in the south and southeast of Elephant Island. The stations completed around the South Orkney Islands were found to be mainly Transition water, or Water Zone III; although very low surface salinities were observed at the stations in the area, this was mainly due to ice melt.

Phytoplankton data:

The data indicate that surface waters were cooler and saltier than average, likely linked to an increased Weddell Sea outflow into the Bransfield Strait and surroundings, leading to deepened surface water mixing. Chl-*a* concentrations were low in waters with salinity >34.2, which is not significantly different from previous years. At salinities below 33.9, Chl-*a* values were significantly less than previous years. Sample data (high fluorescence yield) as well as observational data suggest an onset of nutrient stress, namely iron limitation, in the waters surrounding the South Shetland Islands.

Data from the South Orkney Island survey indicate that the distribution of phytoplankton in relation to hydrographic conditions are vastly different than what has been historically, and is currently, observed in the standard U.S. AMLR survey area.

Bioacoustic data:

Mean krill density was lower in all Areas during the 2007/08 field season than measured during the 2006/07 field season, but higher than measured during the 2005/06 field season. The distribution of mean NASC of myctophids was highest along the 2000m isobath, which is similar to previous years' patterns.

Net – sampling data:

Postlarval krill mean and median abundance values in the Elephant Island Area during Surveys A and D 2008 were among the highest since 1992, rivaling or exceeding peaks recorded in January-February 2003 and 2007 and February-March 1992, 1996, 1998 and 2004. The catch frequency and abundance of postlarval krill were fairly similar between the South Shetland Islands and the South Orkney Islands. However, the majority of the krill found near the South Orkney Islands were one-year-old juvenile and two-year-old immature stages; very few of the mature individuals (only 13% of total krill) were advanced reproductive stages.

The Elephant Island zooplankton assemblage sampled during 2008 was dominated by copepods, postlarval *Thysanoessa macrura,* larval and postlarval, krill and chaetognaths. Although it had a seasonal abundance increase, its overall composition did not change greatly over the survey period. Total mean zooplankton abundance values were fairly similar between the South Orkney Islands and South Shetland Islands, but zooplankton distributions were much more uniform across the South Orkney Islands, most likely due to reduced hydrographic complexity there.

Seabird Research data:

The penguin rookery at Cape Shirreff consisted of 19 sub-colonies of gentoo and chinstrap penguins during the 2007-08 breeding season: A total of 610 gentoo penguin nests and 3,032 chinstrap penguin nests were counted, which are the lowest nest counts observed in 10 years of seabird observation.

Annual recruitment was estimated through population censes and studies of reproductive success in each species. Based on census data, overall gentoo penguin fledging success was 0.89 chicks/nest. This is 33% lower than the previous 10-year mean. Overall chinstrap penguins fledging success was 0.37 chicks/nest, which is 66% lower than the previous 10-year mean. Based on data from our reproductive study, gentoo penguins fledged 0.56 chicks/nest and chinstrap penguins fledged 0.23 chicks/nest. This low reproductive success for both species is also likely explained by high snow cover and inclement weather during clutch initiation and incubation causing numerous nest failures: 54% of gentoo penguins and 75% of chinstrap penguin nests did not hatch any chicks.

A sample of gentoo penguin chicks had an average mass of 4,242g. This is comparable to the previous 10-year mean. Chinstrap penguin fledglings had an average mass of 3,053g. This is slightly (3%) lower than the previous 11-year mean.

Pinniped Research data:

Unfavorable environmental conditions during the 2007/08 breeding season and the winter preceding it resulted in a lower survival rate than average. Over-winter survival of adult females and juveniles decreased this year and is far below the long-term average. Parturition occurred slightly earlier this breeding season than the last. Fur seal pup production during the breeding season was down by 12.5%, and while neonate mortality was lower than most years, Leopard seal predation increased mid-season.

Foraging trip duration increased slightly this year, indicative of poor summer foraging conditions, but remained comparable to the long-term mean. Visit duration also increased over the previous season.

Shipboard seabird and marine mammal observational data:

Seabird feeding aggregations (primarily Cape Petrels *Daption capense*) were observed along the shelf break region from north of King George Island and throughout the Elephant Island Area. The feeding aggregations occurred in proximity to a surface temperature front traversing the West and Elephant Island Areas.

Foraging distributions of Antarctic Fur Seals were widespread in the AMLR Survey Area during Leg I, a distribution pattern that has not been observed since AMLR 2003. Moreover, Antarctic Fur Seals were highly conspicuous in the South stratum, with the highest numbers occurring near the ice edge in the vicinity of the Antarctic Sound and Joinville Island. As in past AMLR surveys, Humpback whales were concentrated in coastal waters near the South Shetland Islands and throughout the deep basins in the Bransfield Strait.

Several seabird feeding aggregations were observed around the northern shelf of the South Orkney Islands, but none were found around the southern shelf. A large number of Fin and Humpback Whales were also observed along the northern shelf, while fewer whales were seen along the southern shelf.

Objectives

Shipboard research:

1. Conduct two surveys in the vicinity of the South Shetland Islands (Leg I) and South Orkneys (Leg II) in order to map meso-scale features of water mass structure, phytoplankton biomass and productivity, zooplankton constituents and the dispersion and population demography of krill.
2. Calibrate shipboard acoustic system at Admiralty Bay the beginning of Leg I and again near the end of Leg II.
3. Collect continuous measurements of ship's position, sea surface temperature, salinity, turbidity, fluorescence, air temperature, barometric pressure, relative humidity, and wind speed and direction. Deploy Continuous Plankton Recorder (CPR) for transits while crossing the Drake Passage (3 north-south transits).
4. Conduct a reduced fur seal census within the Livingston Island area targeting known breeding sites.
5. Collect underway observations of seabirds and marine mammals.
6. Deploy 54 drifter buoys
7. Provide logistical support to field camps at Cape Shirreff, Livingston Island and Admiralty Bay (Copacabana), King George Island.
8. Prepare fur seal milk for lipid analysis, process shore-based collections of fur seal diet samples, collect fur seal and penguin prey (krill, squid and fish) for lipid analysis, bomb calorimetry, and measure krill for validation of krill carapace to total length relationship.

Land-based Research (Cape Shirreff):

1. Estimate chinstrap and gentoo penguin breeding population size.
2. Band 500 chinstrap and 200 gentoo penguin chicks for future demographic studies.
3. Determine chinstrap penguin foraging trip durations during the chick rearing stage of the reproductive cycle.
4. Determine chinstrap and gentoo penguin breeding success and chronologies.
5. Determine chinstrap and gentoo penguin chick weights at fledging.
6. Determine chinstrap and gentoo penguin diet composition, meal size, and krill length/frequency distributions.
7. Deploy time-depth recorders (TDRs) on chinstrap and gentoo penguins during chick rearing for diving studies.
8. Record at sea foraging locations for chinstrap penguins during their chick-rearing period using ARGOS satellite-linked transmitters (PTTs).
9. Monitor female Antarctic fur seal attendance behavior.
10. Collaborate with Chilean researchers in collecting Antarctic fur seal pup mass for 100 pups every two weeks through the season.
11. Collect 10 Antarctic fur seal scat samples every week for diet studies.
12. Collect a milk sample at each female Antarctic fur seal capture for diet studies.
13. Record at-sea foraging locations for female Antarctic fur seals using Platform Terminal Transmitters (PTT) and GPS units.
14. Deploy time-depth recorders (TDR) on female Antarctic fur seals for diving studies.
15. Tag 500 Antarctic fur seal pups for future demographic studies.
16. Collect teeth from selected Antarctic fur seals for age determination.
17. Deploy a weather station for continuous summer recording of wind speed, wind direction, ambient temperature, humidity, and barometric pressure.
18. Conduct an archipelago-wide survey of Antarctic fur seal pup production.
19. Instrument southern elephant seals with conductivity–temperature–depth satellite-relayed data loggers (CTD-SRDLs).
20. Capture and instrument Leopard seals for studies of top-down control of South Shetland Island fur seal populations.

Description of Operations

Shipboard Research:

For the thirteenth consecutive year, the cruise was conducted aboard the chartered research vessel R/V *Yuzhmorgeologiya*. Operations were conducted according to the following schedule:

LEG I:		
Transit to Copacabana	3	11 - 13 Jan
Transfer personnel to Copacabana, calibrate in Admiralty Bay	1	14 Jan
Transfer personnel to Cape Shirreff	1	15 Jan
Reduced SSI Fur Seal survey, Part 1	3	16-18 Jan
Conduct large-area survey	16	19 Jan – 3 Feb
Transfer personnel from Cape Shirreff	1	4 Feb
Reduced SSI Fur Seal survey, Part 2	2	5-6 Feb
Transfer personnel from Copacabana	1	7 Feb
Transit to Punta Arenas	3	8-10 Feb
Total days	31	

LEG II:		
Transit to Cape Shirreff	3	13-15 Feb
Transfer CS & Transit to EI eastern most station (02-01)	2	16-17 Feb
Sample en route to South Orkney Islands	3	18-20 Feb
Conduct five transect survey in South Orkney Islands	8	21-28 Feb
Transit to EI Grid stations 02-09	4	29 Feb-3 Mar
Conduct EI survey	7	4-10 Mar
Transfer personnel from Copacabana/ Calibrate	1	11 Mar
Transfer personnel from Cape Shirreff	1	12 Mar
Transit to Punta Arenas	3	13-15 Mar
Total Days	32	

1. The R/V *Yuzhmorgeologiya* departed Punta Arenas, Chile via the eastern end of the Strait of Magellan and arrived at Cape Shirreff to deliver personnel and supplies to the field camp. The ship then transited to Admiralty Bay to deliver additional personnel and supplies to the Copacabana field camp.
2. The acoustic transducers were calibrated in Admiralty Bay, King George Island. Beam patterns for the hull-mounted 38, 70, 120 and 200kHz transducers were mapped and system gains were determined.
3. Survey components included acoustic mapping of zooplankton, direct sampling of zooplankton, Antarctic krill demography, physical oceanography and phytoplankton observations. Survey A, consisting of 98 (out of 108 planned) Conductivity-Temperature-Depth (CTD) and net sampling stations, separated by acoustic transects, was conducted in the vicinity of the South Shetland Islands (Figure 2). Survey D consisted of 66 stations sampled in the vicinity of the South Shetland Islands (Figure 2), and 49 stations sampled in the vicinity of the South Orkney Islands (Figure 3). Operations at each station included: (a) vertical profiles of temperature, salinity, oxygen, fluorescence, light transmission and collection of water samples at discreet depths; and (b) deployment of an IKMT (Isaacs-Kidd Midwater Trawl) to obtain samples of zooplankton and micronekton. Acoustic transects were conducted between stations at 10 knots, using hull-mounted 38kHz, 70 kHz, 120kHz, and 200kHz down-looking transducers.

4. Seabird and marine mammal observations were collected continuously throughout Legs I and II.
5. Deployed 54 drifter buoys for oceanographic data.
6. Optical oceanographic measurements were conducted, which also included weekly downloads of SeaWiFS satellite images of surface chlorophyll distributions and *in-situ* light spectra profiles.
7. Continuous environmental data were collected throughout Leg I and Leg II including measurements of ship position, sea surface temperature and salinity, fluorescence, air temperature, barometric pressure, relative humidity, wind speed, and wind direction.
8. Fur seal milk was prepared for lipid analysis, shore-based collections of fur seal diet samples were processed, fur seal and penguin prey (krill, squid and fish) were collected for lipid analysis and bomb calorimetry, and krill were measured for validation of krill carapace-to-total-length relationship.

Land-based Research:

1. A five-person field team (R. Haner, G. McDonald, S. Freeman, S. Chisholm and K. Pietrzak) arrived at Cape Shirreff, Livingston Island, on 7 November 2007 via the R/V *Lawrence M. Gould*. Equipment and provisions were also transferred from the R/V *Lawrence M. Gould* to Cape Shirreff.
2. Three additional personnel (M. Goebel, A. Miller and D. Costa), along with supplies and equipment, arrived at Cape Shirreff via the R/V *Yuzhmorgeologiya* 15 January 2008.
3. A region-wide survey of Antarctic fur seal pup production was conducted from 15 January-7 February 2008. A previously unknown colony with a pup production of ~100 pups was discovered on the west-side of Start Pt. on the Beyers Peninsula. Pup production was down 25% over the last region-wide census in 2001/02 but much of the decline can be attributed to poor natality and increased pup mortality on-land and through Leopard seal predation.
4. Antarctic fur seal pups and female fur seals were counted at four main breeding beaches every other day from 12 November 2007 through 4 January 2008.
5. Attendance behavior of 28 lactating female Antarctic fur seals was measured using radio transmitters. Females and their pups were captured, weighed, and measured from 3-14 December 2007.
6. U.S. researchers assisted Chilean scientists in collecting data on Antarctic fur seal pup growth. Measurements of mass for a random sample of 100 pups were begun 30 days after the median date of pupping (6 December 2007) on 5 January 2008 and continued every two weeks until 20 February 2008.
7. Information on Antarctic fur seal diet was collected using scat (random collection of 10 per week) and fatty-acid signature analyses of milk collected at every capture of an adult lactating female.
8. Seventeen Antarctic fur seals were instrumented with time-depth recorders (TDRs) for diving behavior studies.
9. Ten Antarctic fur seal females were instrumented with GPS satellite-linked time depth recorders for studies of at-sea foraging location and diving from 20 December 2007 to 3 February 2008.
10. Four hundred and ninety six Antarctic fur seal pups were tagged at Cape Shirreff by U.S. and Chilean researchers for future demography studies.
11. Weather data recorders (Davis Instruments, Inc.) were set up at Cape Shirreff for wind speed, wind direction, barometric pressure, temperature, humidity, and rainfall.
12. A single post-canine tooth was extracted from ten perinatal female fur seals for aging and demographic studies.
13. Four Leopard seals were captured and instrumented with satellite-linked ARGOS transmitters. All four gave repeated successful locations from deployment in early-February through April.
14. The annual censuses of active gentoo and chinstrap penguin nests were conducted on 10 December and 30 November 2007, respectively. Reproductive success was studied by following a sample of 100 chinstrap penguin pairs and 50 gentoo penguin pairs from egg laying to crèche formation.
15. Radio transmitters were attached to 19 chinstrap penguins on 7 January 2008 and remained on until their chicks fledged in early March 2008. These instruments were used to determine

foraging trip duration during the chick-rearing phase. All data were received and stored by a remote receiver and logger set up at the bird observation blind.

16. Satellite-linked transmitters (PTTs) were deployed on adult chinstrap and gentoo penguins 31 times for seven to ten days at a time. The first deployment coincided with the chick-guard phase, when penguin pairs alternate between attending the nest and foraging. The second deployment was made during the chick crèche phase when both parents forage simultaneously.
17. Diet studies of chinstrap and gentoo penguins during the chick-rearing phase were initiated on 11 January 2008 and continued through 9 February 2008. Forty chinstrap and 20 gentoo adult penguins were captured upon returning from foraging trips, and their stomach contents were removed by stomach lavage.
18. Counts of all gentoo and chinstrap penguin chicks were conducted on 19 and12 February 2008; respectively. Fledging weights of 115 chinstrap penguin chicks were collected, and a total of 128 gentoo penguin chicks were weighed.
19. Two-hundred and fifty chinstrap penguin chicks and 100 gentoo penguin chicks were banded for future demographic studies. These numbers represent half of the number normally banded; extremely poor chick production prohibited banding the full target sample.
20. Reproductive studies of brown skuas and kelp gulls were conducted throughout the season at all nesting sites around Cape Shirreff.
21. Time-depth recorders (TDRs) were deployed a total of 33 times on chinstrap and gentoo penguins for seven to ten days at a time. The first deployment coincided with the chick-guard phase, when penguin pairs alternate between attending the nest and foraging. The second deployment was made during the chick crèche phase when both parents forage simultaneously.
22. The Cape Shirreff field camp was closed for the season on 8 March 2008. All U.S. personnel, garbage and equipment were retrieved by the R/V *Gould.*

Scientific Personnel

Chief Scientist:
Christian Reiss, Southwest Fisheries Science Center (Legs I and II)

Physical Oceanography:
Derek Needham, Sea Technology Services (Legs I and II)
Marcel Van Den Berg, Sea Technology Services (Legs I and II)

Phytoplankton:
Christopher D. Hewes, Scripps Institution of Oceanography (Legs I and II)
Brian Seegers, Scripps Institution of Oceanography (Leg I)
Haili Wang, Scripps Intitution of Oceanography (Leg I)
Kemal Can Bisel, Dokuz Eylul University, Turkey (Legs I and II)
Maria Jose Calderón Nash, Universidad Austral de Chile (Leg I)
Nitza Vera Santana Viviana, Universidad Austral de Chile (Leg II)
Cristina Carrasco, Universidad Católica de Valparaiso, Chile

Bioacoustic Survey:
Anthony Cossio, Southwest Fisheries Science Center (Legs I and II)

Krill and Zooplankton Sampling:
Valerie Loeb, Moss Landing Marine Laboratories (Legs I and II)
Cassandra Brooks (Legs I and II)
Kim Dietrich (Legs I and II)
Darci Lombard (Legs I and II)
Ryan Driscoll (Legs I and II)
Lia Protopapadakis (Legs I and II)
Nicolas Sanchez (Legs I and II)
Kyla Zaret (Legs I and II)

Fur Seal Energetics Studies:
Natalie Spear (Legs I and II)

Seabird and Marine Mammal Observation Studies:
Jarrod A. Santora, College of Staten Island (Legs I and II)
Thomas Brown (Leg I)
Michael Force (Legs I and II)

Cape Shirreff Personnel:
Russell Haner, Camp Leader, Southwest Fisheries Science Center (11/7/07 to 2/4/08)
Gitte McDonald, University of California at Santa Cruz (11/7/07 to 3/8/08)
Scott Freeman (11/7/07 to 3/8/08)
Sarah Chisholm (11/7/07 to 3/8/08)
Kevin Pietrzak (11/7/07 to 3/8/08)
Aileen Miller, Southwest Fisheries Science Center (1/15/08 to 3/8/08), Camp Leader (2/4/08 to 3/8/08)
Michael E. Goebel, Southwest Fisheries Science Center (1/15/08 to 2/4/08)
Daniel P. Costa, University of California at Santa Cruz (1/15/08 to 2/4/08)

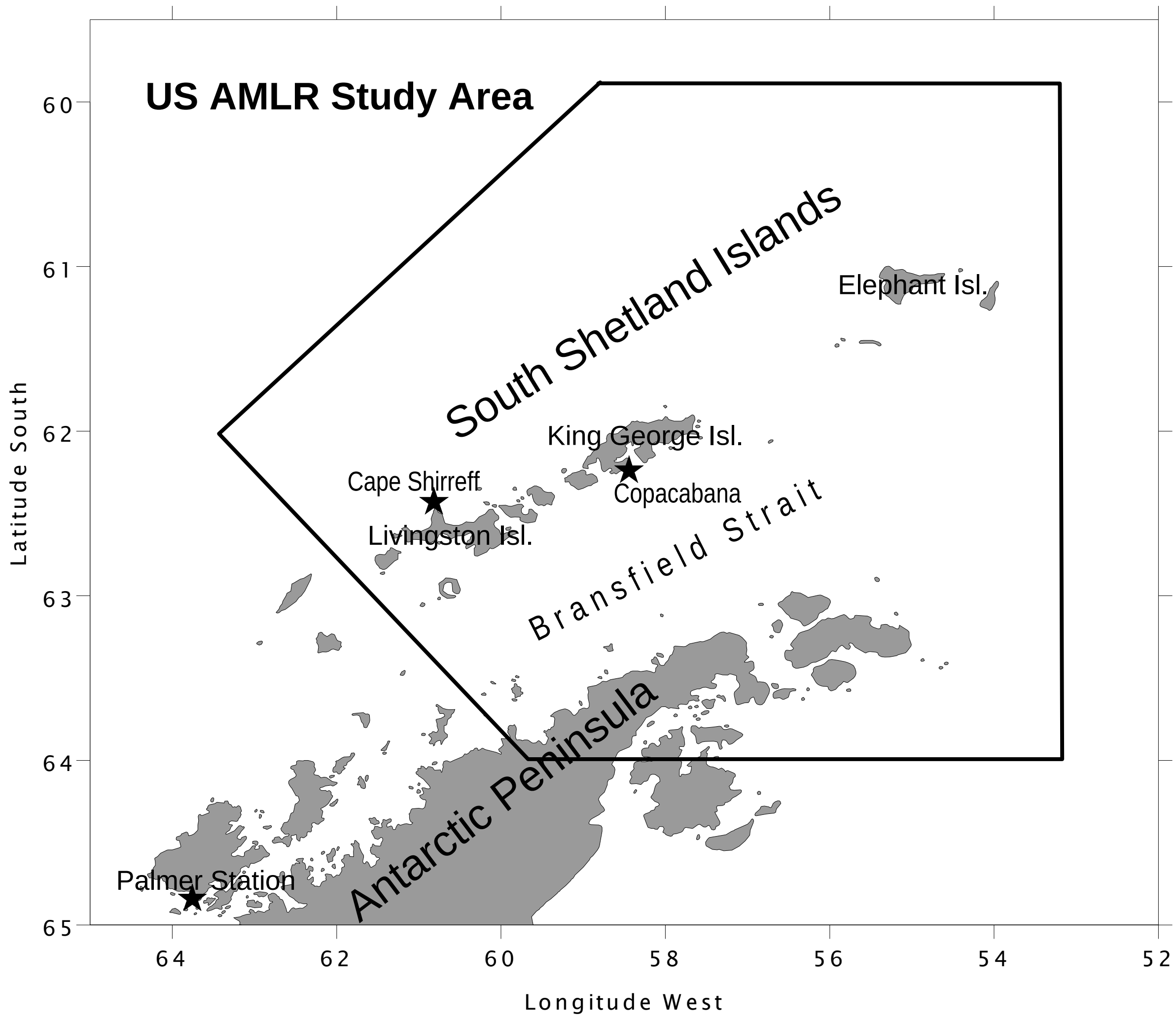


Fig 1. Locations of the U.S. AMLR field research program: AMLR study area; Cape Shirreff, Livingston Island; Copacabana, King George Island.

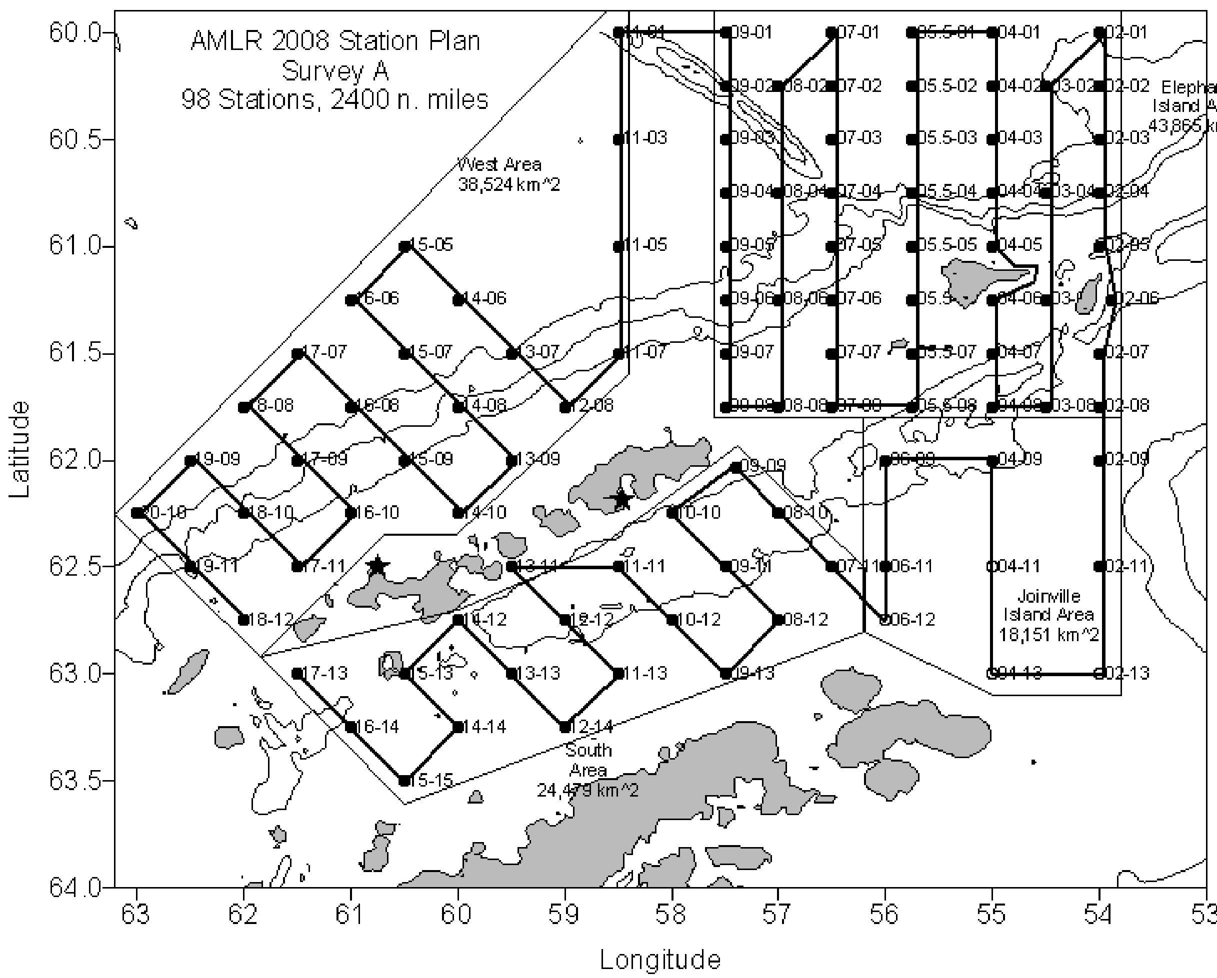


Figure 2. The survey design for AMLR 2007/08 (Survey A & D) in the vicinity of the South Shetland Islands; field camp locations indicated by★. The survey contains four strata outlined by thin lines: the stratum containing stations in the western portion of the survey area north of Livingston and King George Islands is designated the West Area, the stratum located south of King George Island is designated the South Area, the stratum containing stations in the northern portion of the South Shetland Islands is designated the Elephant Island Area, and the stratum south of Elephant Island is designated the Joinville Island Area. Depth contours are 500m and 2000m. Black dots indicate the location of biological/oceanographic sample stations; heavy lines indicate transects between stations.

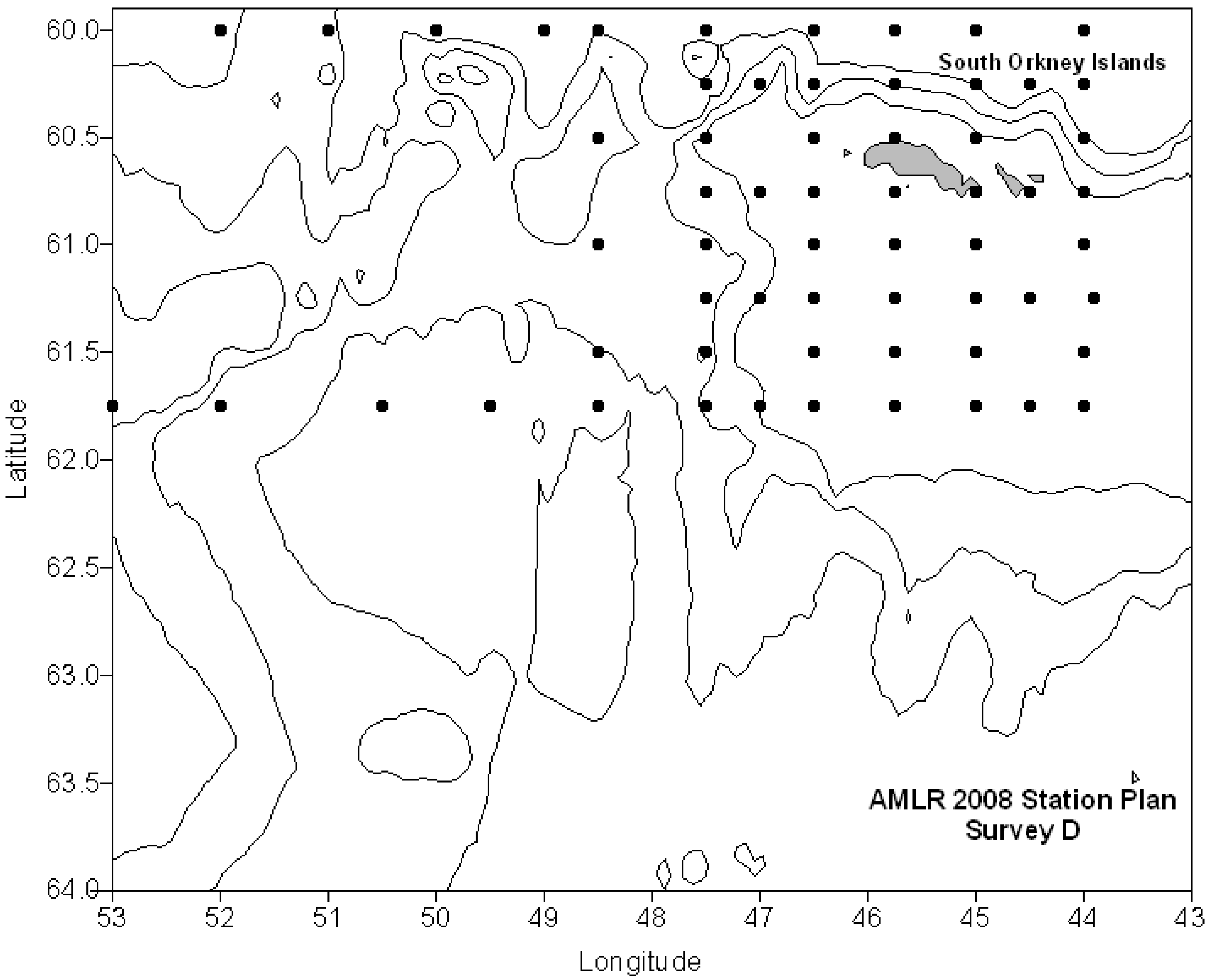


Figure 3. The survey design for AMLR 2007/08 (Survey A & D) in the vicinity of the South Orkney Islands. The survey was conducted on the northern and southern shelves of the Islands. Depth contours are 500m and 2000m. Black dots indicate the location of biological/oceanographic sample stations; heavy lines indicate transects between stations.

1. Physical Oceanography and Underway Environmental Observations; submitted by Derek Needham(Leg I), Marcel van den Berg(Legs I&II) and Johan Kritzinger(Leg II).

1.1 Objectives: Objectives were to 1) collect and process physical oceanographic data in order to identify hydrographic characteristics and map oceanographic frontal zones; and 2) collect and process underway environmental data in order to describe sea surface and meteorological conditions experienced during the surveys

1.2 Accomplishments:

1.2.1 Hydrographic Data Collection: A total of 224 CTD/carousel casts were completed, 99 of these as part of Leg I (Survey A) and 115 as part of Leg II (65 as part of Survey D and 50 casts in the South Orkney Island Area). Eight additional casts were done (See Figure 2 in the Introduction for station locations). Two CTD casts were also completed during acoustic calibrations in Admiralty Bay at the beginning and end of the cruise.

A total of 73 Expendable Bathy Thermographs (XBT's) were deployed to compliment the data collected from the CTD casts (57 during Survey A, 16 during Survey D and the South Orkney Island area). These were mainly deployed during transits between stations and at cancelled stations. Three XBT transects (60 casts) were completed during the Drake Passage crossings (two transects from North to South, and one from South to North during Leg II).

Four stations (A11-05; A11-03; A02-02 and A02-04) were cancelled during Leg I due to bad weather. One additional station (A03-14) was added to the existing survey area at the most southern point reached in the Joinville Island Area. During Leg II, two stations (SO-001 and SO-010) were cancelled due to bad weather.

Water samples were collected at 11 discrete depths on all casts and used for salinity and phytoplankton analysis. These were drawn from Niskin bottles by the Russian scientific support team. Salinity calibration samples from all stations were analyzed on board, using a Guildline Portasal salinometer. Close agreements between CTD measured salinity and the Portasal values were obtained, with an average error of 0.0016 %. The final CTD/Portasal correlation produced an r^2=0.9964 (n= 1069) during the cruise. Comparisons of dissolved oxygen levels in the carousel water samples and the levels measured during the casts (via the O_2 sensor) were not attempted during the survey.

Underway comparisons of the Sea-Bird SBE-21 thermosalinograph (TSG) with CTD data were undertaken during the main survey. Salinity data compared with 5m CTD salinity data showed that the TSG salinity reading were on average 0.051ppt (n=216) lower than the CTD, while the sea temperature showed the TSG to be on average 0.529°C (n=216) higher than the CTD 7m temperature data. This can be attributed to the heating effects of positioning the temperature sensor downstream of the seawater pump.

1.2.2 Underway Environmental Data Collection: Environmental and vessel positional data was collected for a total of 61 days (30 days and 31 days during Legs I and II respectively) via the Scientific Computer System (SCS) software package. The data collected covered surface environmental conditions encountered over the South Shetland Islands and South Orkney Islands for the duration of the cruise, as well as transits to and from Punta Arenas, Chile.

1.3 Methods:

1.3.1 Hydrographic Data Collection:

Water profiles and samples were collected with a Sea-Bird SBE 911plus CTD system and Sea-Bird SBE 32 carousel water sampler equipped with eleven 101itre sampling bottles. A Sea-Bird SBE 43 dissolved oxygen probe, SBE pump, Chelsea Instruments Aquatracka III fluorometer, Wetlabs C-Star red transmissometer and a Wetlabs C-Star blue transmissometer were added to the CTD system. A Biospherical QCP-2300 2pi PAR sensor was also added. The QCP200L PAR sensor, used on previous cruises, was retained on the system to obtain a cross calibration between the two (Table 1.1). Scan rates were set at 24 scans/second during both down and up casts. Sample bottles were triggered during the up casts. Profiles were limited to a depth of 750m or 5m above the sea bottom when shallower than 750m. A Data Sonics altimeter was used to stop the CTD descent 5 to 7m from the seabed during shallow casts. Standard sampling depths were 750m, 200m, 100m, 75m, 50m, 40m, 30m, 20m, 15m, 10m and 5m.

The SCS software (SCS Version 3.3a) used to record and compare data ran on a Windows XP based Pentium IV Dell PC with an Edgeport-8 USB serial port expander. A Coastal Environmental Company Weatherpak system, a Licor quantum PAR sensor and a Biospherical 4PI QSR-2100 PAR sensor were installed on the port side of the forward A-frame in front of the bridge and were used as the primary meteorological data acquisition system.

Plots of the down and up traces were generated and stored with the CTD cast log sheets. Various phytoplankton groups received copies of the data, together with CTD mark files (reflecting data from the cast at bottle triggering depths) and processed down traces in Ocean Data View (ODV) format. Data from casts were averaged over 1m bins and saved separately as up and down traces during post processing. The data was logged and bottles triggered using Sea-Bird Seasave Win32 Version 5.30a software and the data processed using SBE Data Processing Version 5.30a software. Downcast data was re-formatted using a SAS script and then imported into ODV for further analysis.

Before leaving port and during Leg I, various tests were undertaken to compare the performance of the CTD's two PAR sensors against the two masthead PAR sensors. An extended-period cross calibration of the PAR sensors was undertaken in port between Legs I and II.

1.3.2 Underway Environmental Data Collection: Weather data inputs were provided by the Coastal Environmental Systems Company Weatherpak via a serial link. Data included relative wind speed and direction, barometric pressure, air temperature and irradiance (PAR). A Biospherical 4PI QSR-2100 PAR sensor (RS232 output version) was installed on the forward gantry, near the Weatherpak, and interfaced to the Scientific Computer System (SCS). The relative wind data were converted to true speed and true direction by the internally derived functions of the SCS logging software. Measurements of sea surface temperature and salinity were received by the SCS, in serial format, from the Sea-Bird SBE 21 thermosalinograph (TSG) and integrated into the logged data. Ship position and heading were provided in NMEA format via a Trimbol GPS Navigator and Guiys Gyro, respectively. Serial data lines were interfaced to the Pentium 4 (Windows XP Professional based) logging PC via an Edgeport 8 serial RS232 to USB interface.

1.4 Results and Tentative Conclusions:

1.4.1 Oceanography:

The position of the polar frontal zone, identified by pronounced sea surface temperature and salinity change, was located from the logged SCS data during the two transits from and to Punta Arenas and the South Shetland Islands Survey Area. This frontal zone is normally situated between 57-58° S.

During the south-bound transit of Leg I, a narrow front was defined between 58° 05'S and 58°' 15'S, with sea surface temperature (SST) changing from 4.5°C to 3.1°C. During the north-bound transect the front was located between 57°15'S and 56°50'S, with a change in SST from 3.4°C to 4.3°C. During the south-bound transit of Leg II the front was found to have moved further south and broadened when compared to the north bound transect of Leg I, laying between 57° 30' S and 58° 55' S, with the SST changing from 6.7°C to 3.1°C. On the return (north-bound) transit, at the end of Leg II, the zone was located between 57° 20' S and 58° 15' S, with the SST changing from 4.0°C to 6.5°C. (Figure 1.1) Two of the three XBT transects across the Drake Passage were plotted for comparison reasons for the North to South transects for Legs I and II respectively. The 1.8°C temperature isotherm was highlighted to show the Polar fronts, which coincide with the data obtained from the logged SCS data (Figure 1.2).

As in previous years, an attempt was made to group stations with similar temperature and salinity profiles into five Water Zones as defined in Table 1.2. The tentative Water Zone classifications according to the criteria in Table 1.2 were sometimes prone to ambiguity, particularly in the coastal regions around King George & Livingston Islands and in the south and southeast of Elephant Island. Classifications of Zone IV (Bransfield Strait) and V (Weddell Sea) waters in these areas could change if other oceanographic data such as density are considered. For the purpose of this report, in which only tentative conclusions are reported, only the criteria contained in Table 1.2 were used. This was done to ensure consistency with past cruises and only serves as a first attempt field classification.

During Leg I, there was a defined distinction of Zone I (ACC) water at the offshore stations of the West area (63% of stations), with the inshore stations being Zone IV (Bransfield Strait) water. The Fracture Zone, in the Elephant Island Area, was classified as containing ACC water, or Water Zone I (transects 09; 08 and 07), with Zone II (Transition) water in the northeastern part of the Area. The southern extent of the Elephant Island Area was classified as Water Zone IV (Bransfield Strait), with 3 stations towards the south east of the area being Water Zone V (Weddell Sea). Ten stations were occupied in the Joinville Island area, with 80% of these stations being classified as Water Zone V (Weddell Sea). In the South Area the stations along the Peninsula was classified as Water Zone V (Weddell Sea) with the remainder of the stations (74%) in the area being classified as Water Zone IV (Bransfield Strait) (Figure 1.3).

During Leg II the West Area was not sampled; only the Elephant Island and South Areas were completed as part of survey D. Comparing data from these two areas with Leg I data shows that the water located along the northern extent of the Elephant Island Area had become more Zone II (Transition) waters, with 40% of stations being classified as Zone II (transition) compared to 28% during Leg I. The southern extent of the Elephant Island Area was still mainly classified as Zone IV (Bransfield Strait) waters, with 3 stations on the eastern side of the area classified as Zone V (Weddel Sea) waters. The South Area was, as with Leg I of the survey, mainly classified as Zone IV (Bransfield Strait) water (83% of stations) (Figure 1.3).

The stations completed around the South Orkney Islands were found to be mainly Transition water, or Water Zone III (Figure 1.4); although very low surface salinities were observed at the stations in the area, this was mainly due to ice melt.

Three vertical temperature transects - identical to transects from previous years, for comparative value - were plotted using ODV software from the main survey (Figure 1.5). These transects are W05 in the West Area and EI03 and EI07 in the Elephant Island Area of the survey. Transect W05 in the West Area was not sampled during Leg II.

1.4.2 Underway Data: Environmental data were recorded for the duration of the surveys and during the transits between Punta Arenas and the survey area. Processed data were averaged and filtered over 1-minute and 5-minute intervals. (Figures 1.6; 1.7 and 1.8: Leg I, the South Orkney Islands and Leg II respectively).

Summary tables of the underway data collected during the survey were created (Tables 1.3 and 1.4) using 5-minute average values. Mean PAR values was calculated using *mid-day* values only (10:00 – 14:00).

Using PAR results obtained, which indicate levels of photosynthetic radiation, it can be observed that cloud cover during Survey A was less (t=12.6, p=0.000) than during Survey D. Air temperature was higher for Survey A compared to Survey D (2.3°C and 2.1°C respectively; t=3.9, p=0.000).

Wind direction during Survey A was predominately west to northwest (45% and 36% respectively) with wind speeds averaging 19 knots. During Survey D the average wind speed was lower (17.8 knots; t=7.0, p=0.000), with wind direction still mainly from the west and northwest (24% and 26% respectively).

1.5 Problems and Suggestions

In general the CTD systems performed well during the cruise; only the usual maintenance to leaking underwater connectors was required. A continuous check was done on CTD performance by frequently processing data and checking for signs of sensor drift. Only one SBE 9plus underwater unit (and its auxiliary instruments) was used for both legs of the cruise. The SBE 43 Oxygen Sensor was replaced with a spare unit during Leg II due to malfunction. Four sampling bottles were damaged beyond repair during the cruise. The process of replacing the existing sampling bottles should be started before the next cruise.

There is an ongoing problem with the ship's clean seawater supply and the TSG debubbler plumbing system that was not resolved during the cruise. The pump is too powerful and cavitates, causing excessive bubbles that the debubbler cannot clear fast enough. This causes spiking on the salinity trace. Continual cleaning and monitoring of the pump was required by ship staff to reduce the amount of bubbles. It is suggested that the pump and debubbler system be replaced by the ship and that a new Sea-Bird SBE 45 TSG be bought to be used as the operational unit and the existing SBE 21 TSG be used as the spare, as there is no spare TSG at present. This practice of gradual upgrading and replacement of instruments and systems is recommended to phase out old equipment and keep abreast of new oceanographic technology.

A field calibration was done on the Chelsea Instruments submersible fluorometer. Results provided in the phytoplankton section (Chapter 2).

There is a discrepancy between the calibration of the four PAR sensors on the ship (two submersible and two mast mounted). It is suggested that all four sensors be post-cruise calibrated together.

Besides the technical support for the oceanographic operation, general technical support was given to assist in solving a number of equipment related problems (electronic, software, mechanical and operational).

1.6 Disposition of Data: Data are available from Christian Reiss, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA, 92037; phone/fax (858) 546-5603/(858) 546-5608; email: Christian.Reiss@noaa.gov.

1.7 Acknowledgements: The co-operation and assistance of the Russian technical support and deck staff was once again outstanding. All requests for assistance were dealt with effectively and in a professional manner.

1.8 References:

Schlitzer, R., Ocean Data View, http://www.awi.bremerhaven.de/GEO/ODV, 2001.

Table 1.1. CTD/Sensor installation summary (AMLR2008)

Description	**Manufacture**	**Model**	**LEG I**	**LEG II**
Deck Unit	Sea-Bird	SBE 11	11P13966-0434	11P13966-0434
U/W Unit	Sea-Bird	SBE 9plus	09P13966-0454	09P13966-0454
Temperature Sensor	Sea-Bird	SBE 3plus	3P2234	3P2234
Conductivity Sensor	Sea-Bird	SBE 4C	041815	041815)
Pressure Sensor	DigiQuartz 410K-105	Internal	64268	64268
Circulation Pump	SeaBird	SBE 5T	051654	051654
SBE Carousal	Sea-Bird	SBE 32	3235861-0509	3235861-0509
O_2 Sensor	Sea-Bird	SBE 43	430908 (Voltage 0)	430908/430912 (Voltage 0)[1]
PAR (new)	Biospherical	QCP-2300	4744 (Voltage 2)[2]	
Altimeter	Datasonics	PSA-900	508 (Voltage 3)	508 (Voltage 3)
PAR (old)	Biospherical	QCP200L	4264 (Voltage 4)[3]	4264 (Voltage 2)
Transmissometer	Wetlabs	C-Star (Blue)	CST-421DB (Voltage 5)	CST-421DB (Voltage 5)
Fluorometer	Chelsea	Aqua 3	05-5173-001 (Voltage 6)	05-5173-001 (Voltage 6)
Transmissometer	Wetlabs	C-Star (Red)	CST-882DB (Voltage 7)	CST-882DB (Voltage 7)

[1] Change O2 sensor after Station SO-012 from SN#430908 to SN#430918 due to malfunction (New configuration file – 09p-0454_AMLR2008_Leg2a)

[2] Remove and change to PAR(old) – SN#4264 - after station A03-08

[3] Remove PAR sensor after station A11-01 ; Transmissometer (voltage 5) moved to voltage 4 (new confile 09p-0454_AMLR2008_leg1C)

Table 1.2. Water Zone definitions applied for AMLR 2007/08.

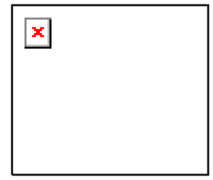
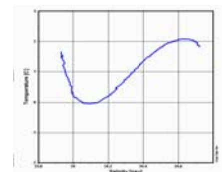
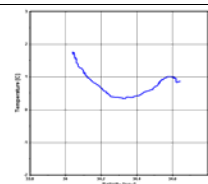
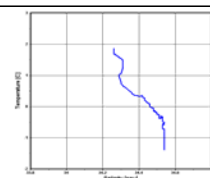
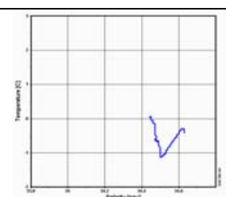
	T/S Relationship			
	Left	**Middle**	**Right**	**Typical TS Curve (from 2002)**
Water Zone I (ACW)	**Pronounced V shape with V at ≤0ºC**			
Warm, low salinity water, with a strong subsurface temperature minimum, Winter Water, approx. -1ºC, 34.0ppt salinity) and a temperature maximum at the core of the CDW near 500m.	2 to >3ºC at 33.7 to 34.1ppt	≤0ºC at 33.3 to 34.0 ppt	1 to 2ºC at 34.4 to 34.7ppt (generally >34.6ppt)	
Water Zone II (Transition)	**Broader U-shape**			
Water with a temperature minimum near 0ºC, isopycnal mixing below the temperature minimum and CDW evident at some locations.	1.5 to >2ºC at 33.7 to 34.2ppt	-0.5 to 1ºC at 34.0 to 34.5ppt (generally >0ºC)	0.8 to 2ºC at 34.6 to 34.7ppt	
Water Zone III (Transition)	**Backwards broad J-shape**			
Water with little evidence of a temperature minimum, mixing with Type 2 transition water, no CDW and temperature at depth generally >0ºC	1 to >2ºC at 33.7 to 34.0ppt	-0.5 to 0.5ºC at 34.3 to 34.4ppt (note narrow salinity range)	≤1ºC at 34.7ppt	
Water Zone IV (Bransfield Strait)	**Elongated S-shape**			
Water with deep temperature near -1ºC, salinity 34.5ppt, cooler surface temperatures.	1.5 to >2ºC at 33.7 to 34.2ppt	-0.5 to 0.5 ºC at 34.3 to 34.45ppt (T/S curve may terminate here)	<0ºC at 34.5ppt (salinity < 34.6ppt)	
Water Zone V (Weddell Sea)	**Small fish-hook shape**			
Water with little vertical structure and cold surface temperatures near or < 0ºC.	1ºC (+/- some) at 34.1 to 34.4ppt	-0.5 to 0.5ºC at 34.5ppt	<0ºC at 34.6ppt	

Table 1.3. Mean environmental variables (5-minute average values) by survey and area. Mean PAR calculated using mid-day values only (10:00- 14:00).

Survey	A					D			South Orkneys
Area	**Elephant**	**Joinville**	**South**	**West**	**Total**	**Elephant**	**South**	**Total**	
N / N for PAR	2503 / 402	474 / 96	804 / 144	951 / 174	4732 / 816	1929 / 336	815 / 108	2787 / 480	2798 / 456
Wind Speed (knots)	22.0	13.4	13.6	18.2	19.0	19.9	12.8	17.8	21.1
Air Temp (°C)	2.8	-0.4	1.9	2.7	2.3	2.2	2.1	2.1	1.4
Barometric Pressure (mb)	997.6	989.5	992.8	991.9	994.8	1005.0	991.4	1001.0	987.3
Humidity (%)	91.7	91.3	90.9	91.3	91.5	90.0	93.1	91.0	91.8
Water Temp (°C)	1.7	0.2	1.4	1.8	1.5	2.0	1.3	1.8	0.8
Salinity (ppt)	34.0	34.3	34.1	34.0	34.1	34.0	34.1	34.1	33.5
PAR (μEin/m²/s)	538.0	336.6	603.4	343.3	484.3	273.3	239.7	259.1	388.7

Table 1.4. Percent wind direction by survey and area (from 5-minute average values).

Survey	A					D			South Orkneys
Area	**Elephant**	**Joinville**	**South**	**West**	**Total**	**Elephant**	**South**	**Total**	
E	1%	3%	0%	0%	**1%**	8%	8%	**8%**	2%
N	7%	4%	8%	11%	**8%**	6%	13%	**8%**	8%
NE	1%	0%	1%	0%	**0%**	20%	13%	**17%**	5%
NW	32%	25%	22%	64%	**36%**	23%	27%	**24%**	31%
S	0%	28%	0%	0%	**3%**	6%	0%	**5%**	2%
SE	0%	12%	1%	0%	**2%**	9%	0%	**6%**	1%
SW	6%	12%	8%	0%	**6%**	8%	2%	**6%**	14%
W	53%	15%	59%	24%	**45%**	20%	37%	**26%**	36%

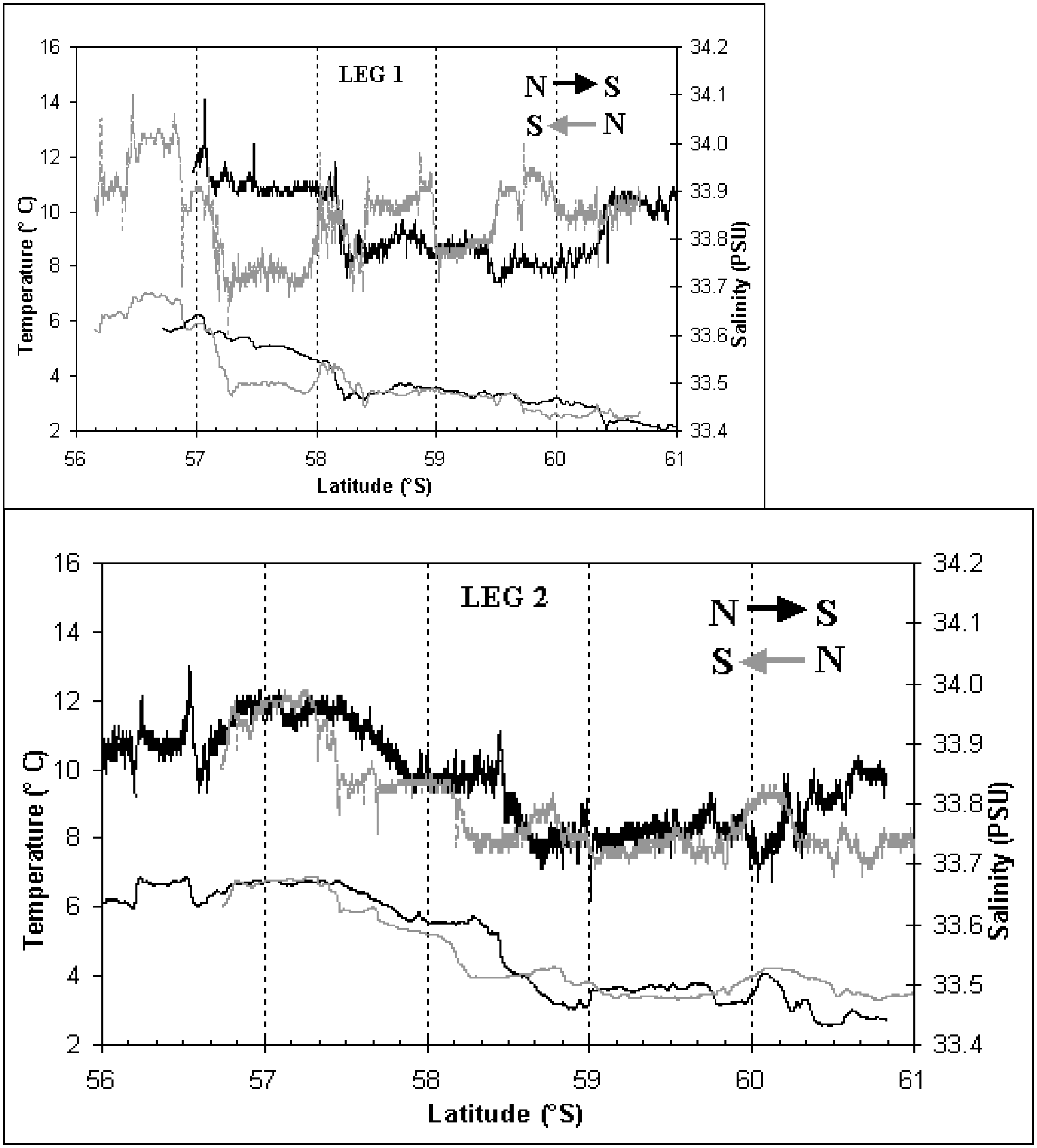


Figure 1.1. The position of the polar fronts as determined for AMLR 2007/08 Legs I (top) and II (bottom), from measurements of sea surface temperature (solid line) and salinity (broken line) for the south and north transits to and from the South Shetland Islands Survey area.

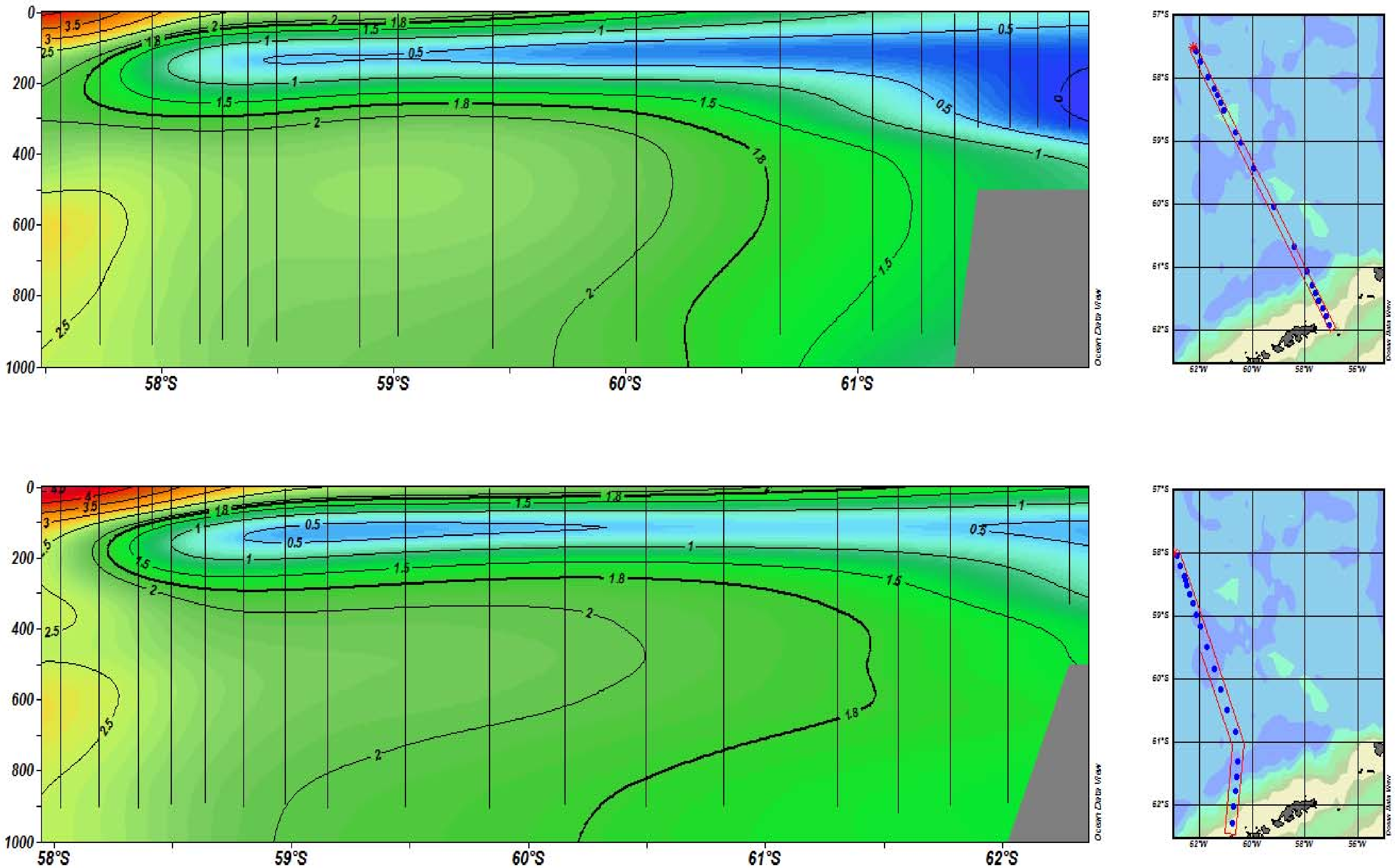


Figure 1.2. XBT (Expendable Bathy Thermograph) temperature data for AMLR 2006/07: North/South transect (top) and South/North transect (bottom).

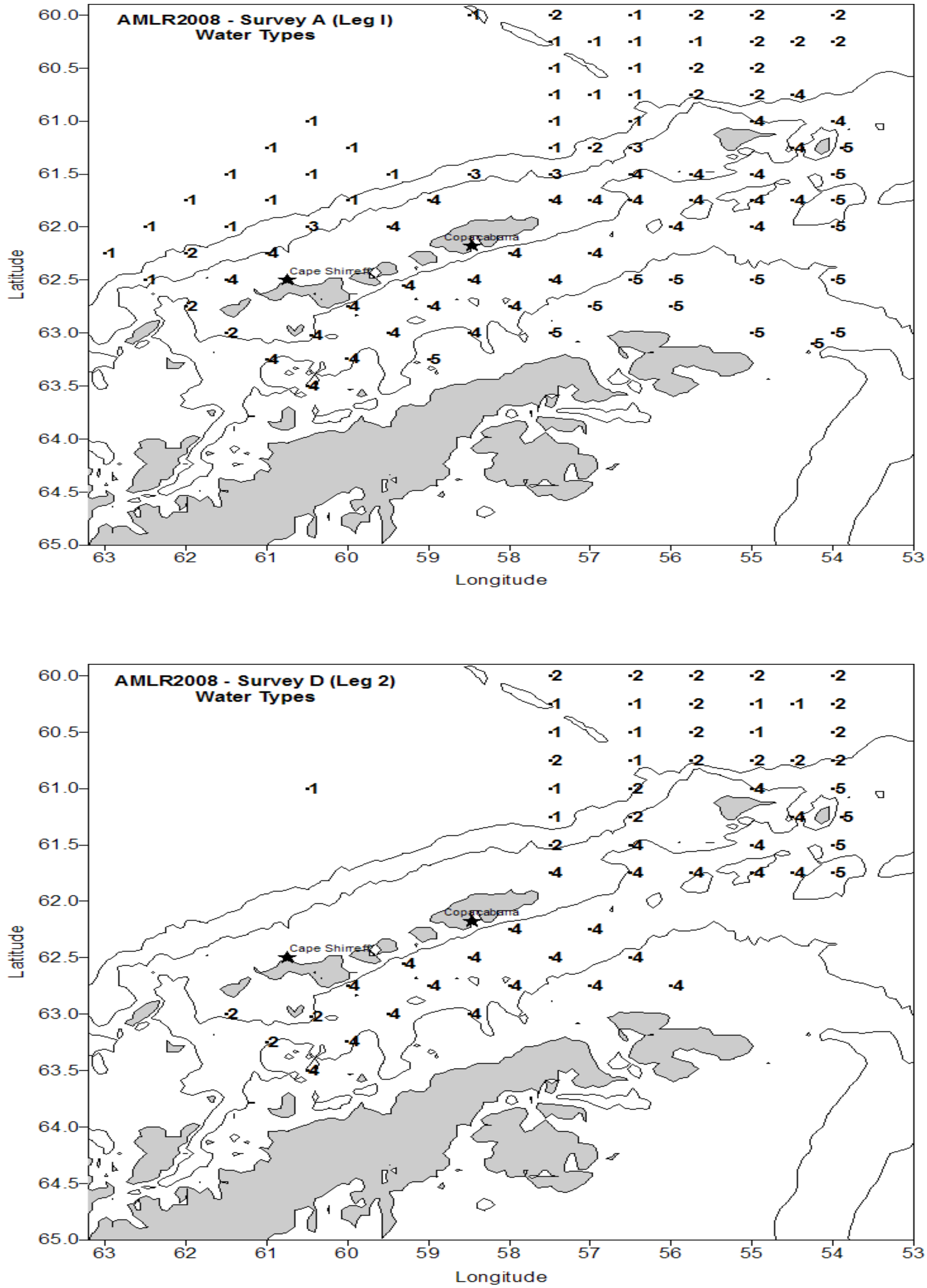


Figure 1.3. Classification of water zones for Leg I & II (top and bottom panels, respectively) for AMLR 2007/08, as defined in Table 1.1 (Water Zone definitions).

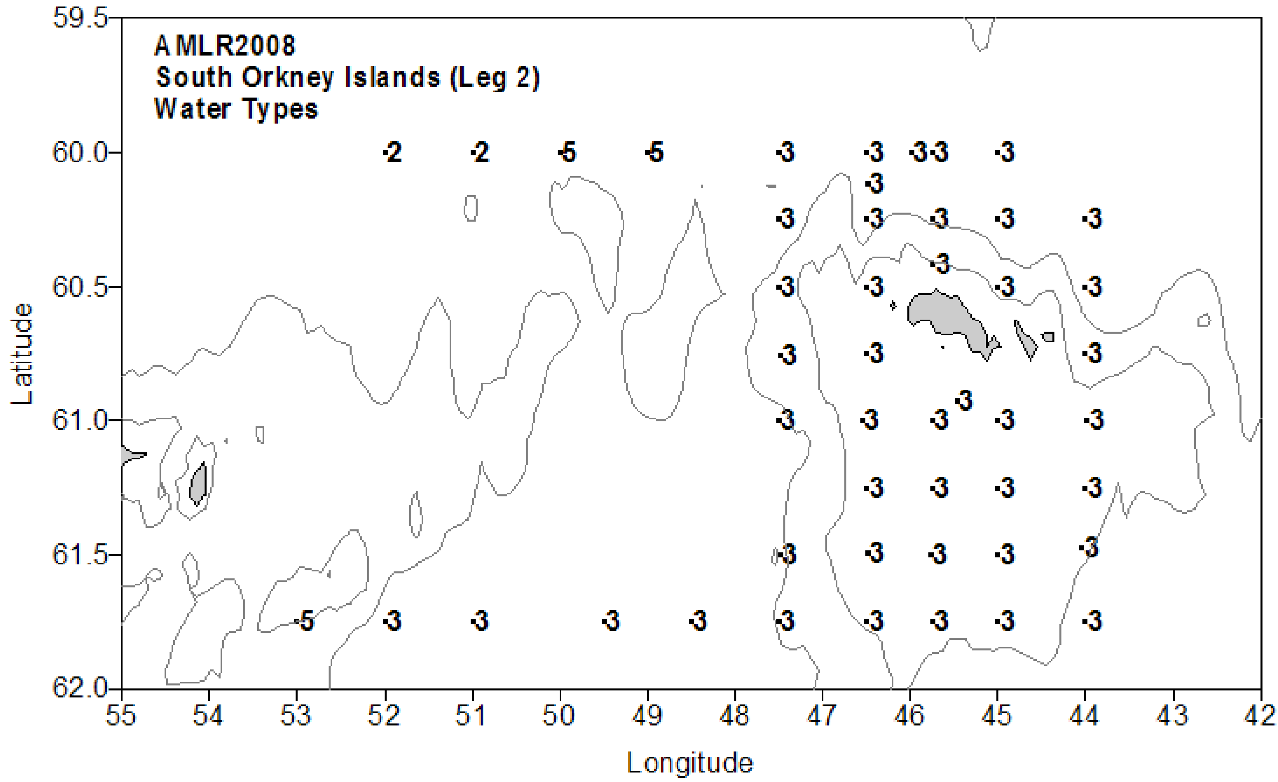


Figure 1.4. Classification of water zones for the South Orkneys Islands (Leg II) for AMLR 2007/08, as defined in Table 1.1 (Water Zone definitions).

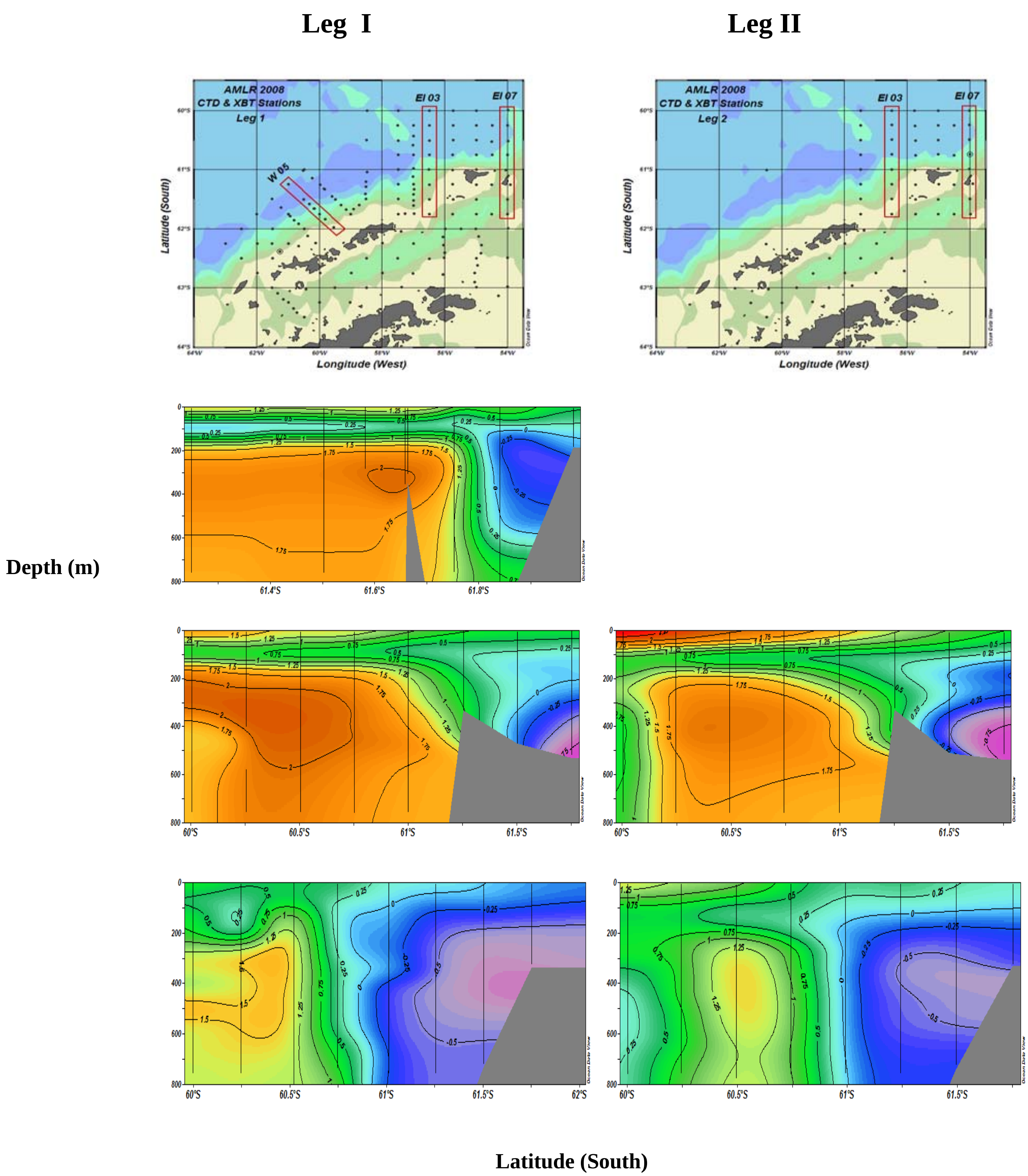


Figure 1.5. Vertical temperature profiles derived from CTD data recorded on three transects, W 05 (top), EI 03 (middle) and EI 07 (bottom), during Legs I (left column) and II (right column) of the the AMLR 2007/08 South Shetland Island survey. Transect W 05 not sampled during Leg II

AMLR 2007/08 – Leg I (Survey A)

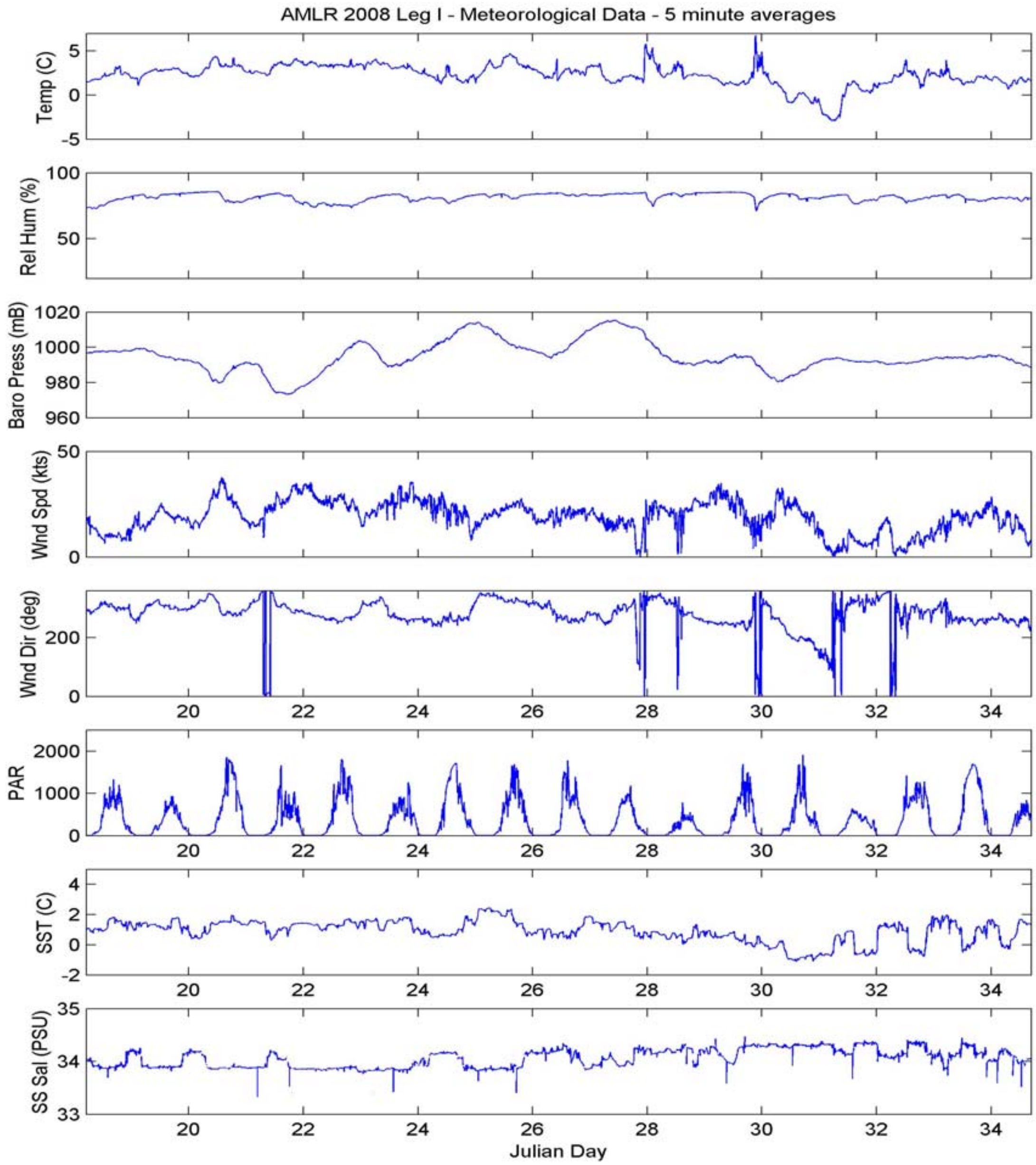


Figure 1.6. Meteorological data (5 minute averages) recorded between January 18th and February 3rd during Leg I (survey A only) of the AMLR 2007/08 cruise. (PAR is photo-synthetically available radiation).

AMLR 2007/08 – Leg II (South Orkney Islands)

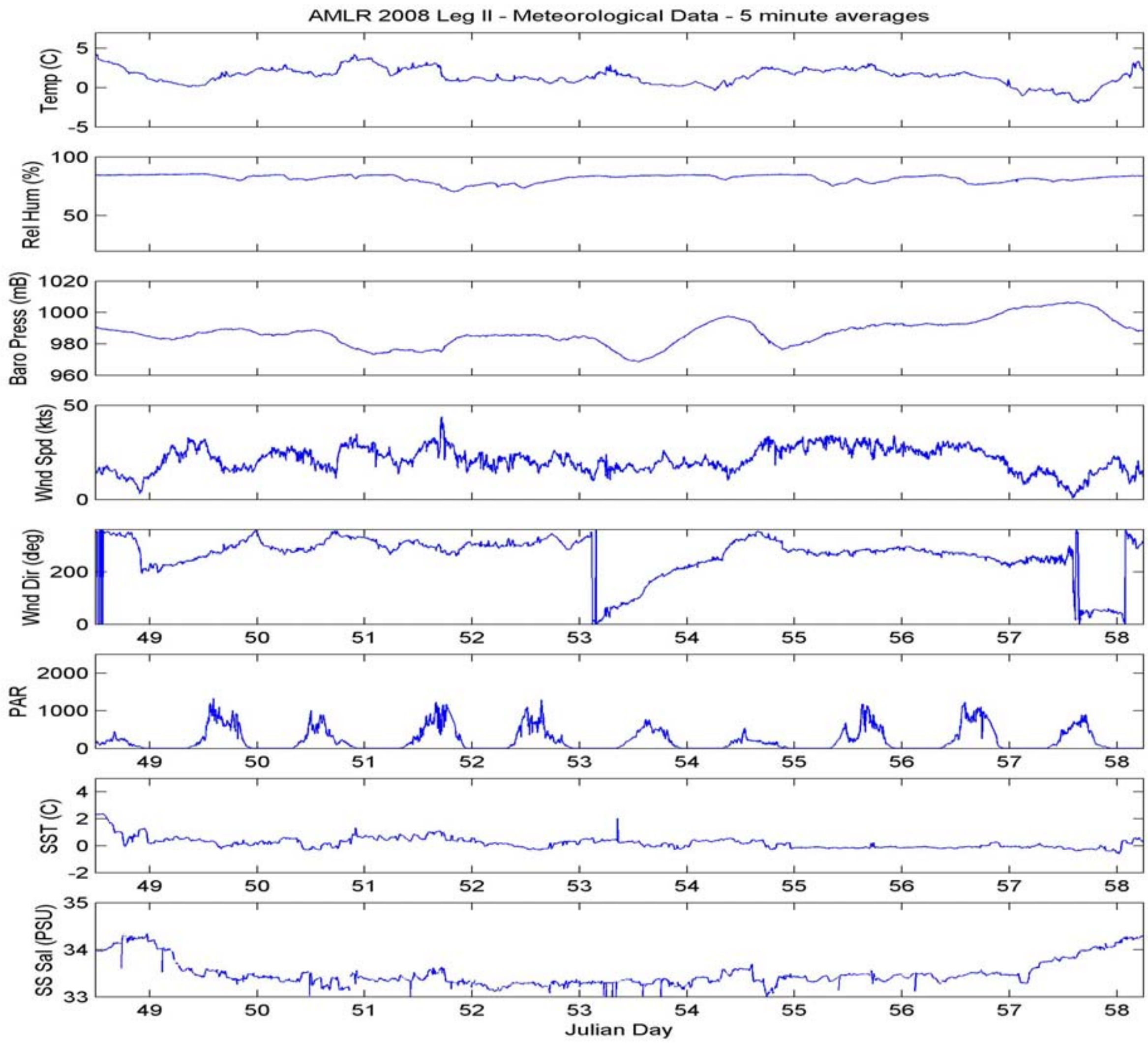


Figure 1.7. Meteorological data (5 minute averages) recorded between February 17th and February 27th during Leg II (South Orkney islands only) of the AMLR2007/08 cruise. (PAR is photo-synthetically available radiation).

AMLR 2007/08 – Leg II (Survey D)

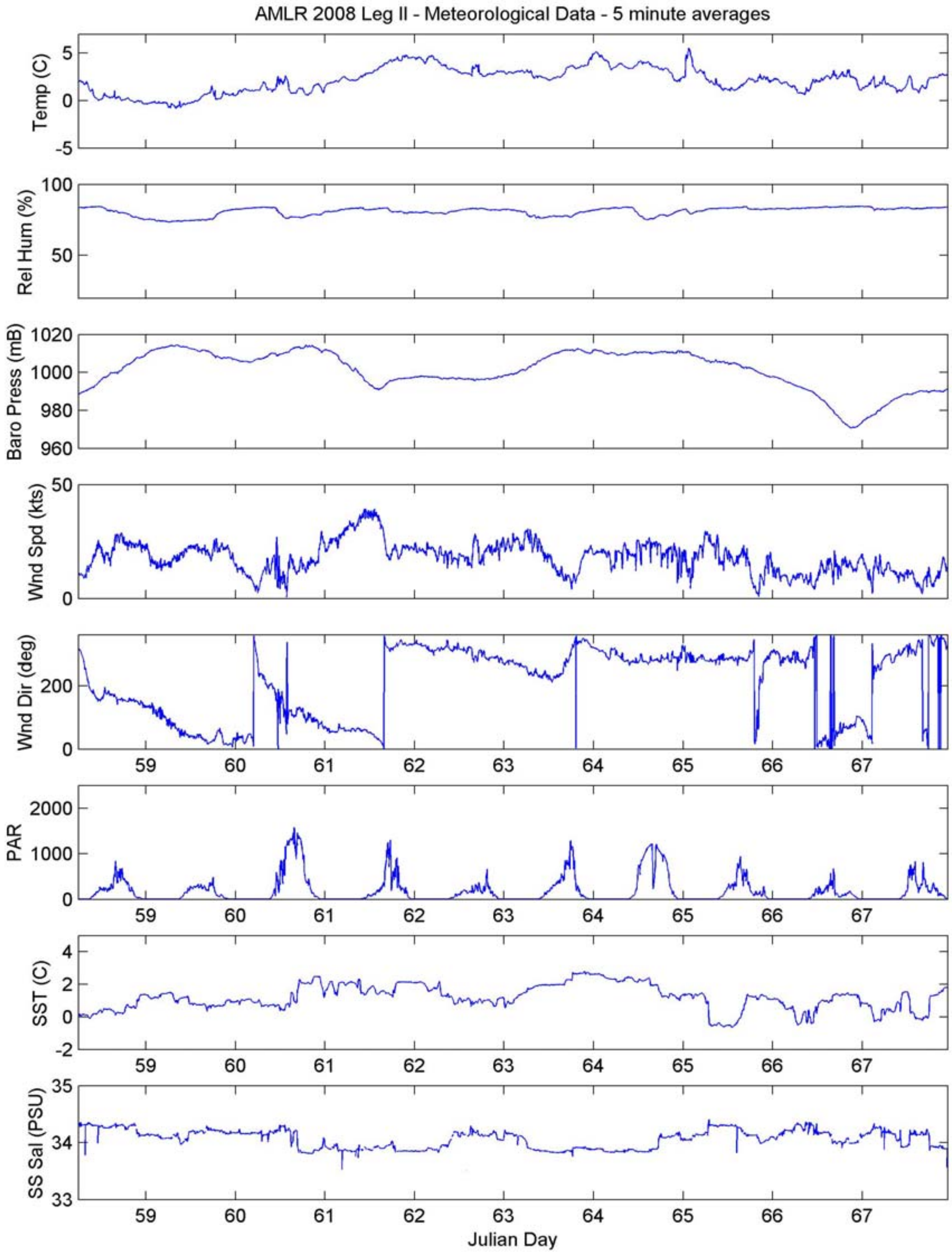
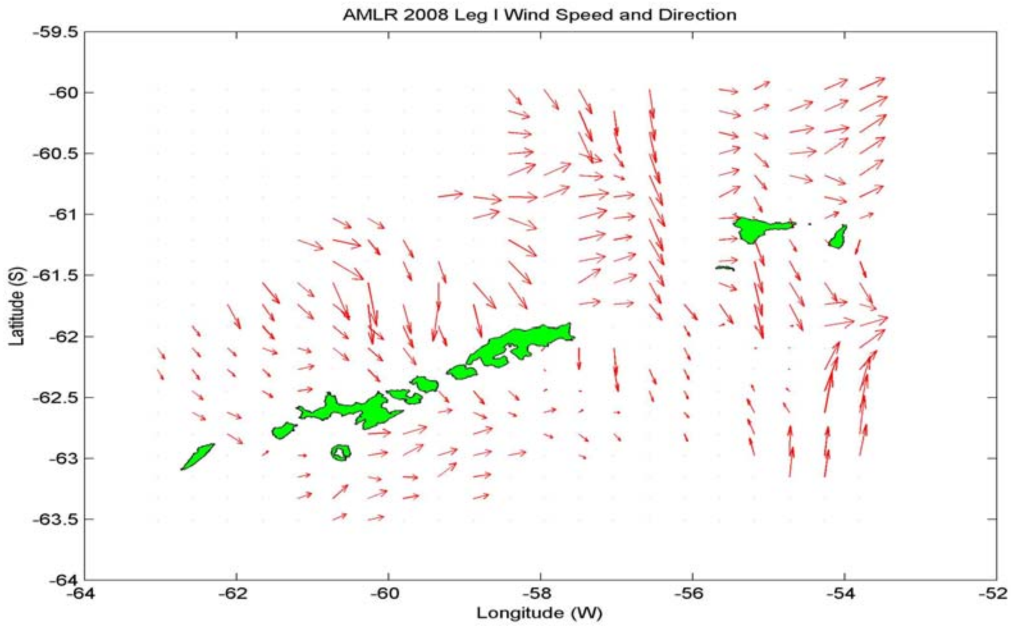


Figure 1.8. Meteorological data (5 minute averages) recorded between February 27th and March 7th during Leg II (survey D only) of the AMLR2007/08 cruise. (PAR is photo-synthetically available radiation).



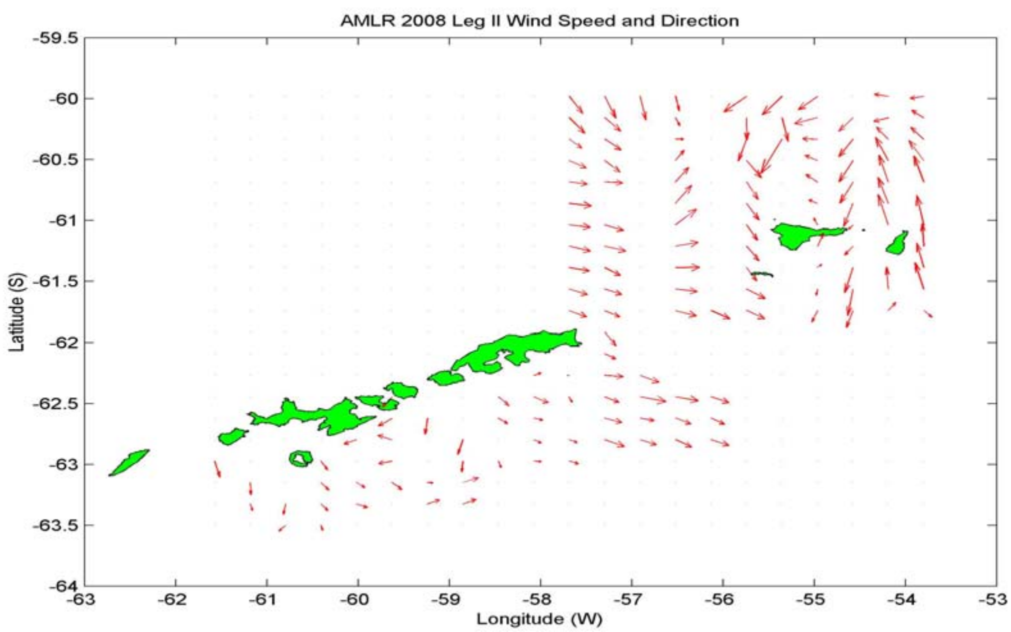


Figure 1.9. Vectors representing wind speed and direction for Legs I (top) & II (bottom), derived from data recorded by the SCS logging system during AMLR 2007/08.

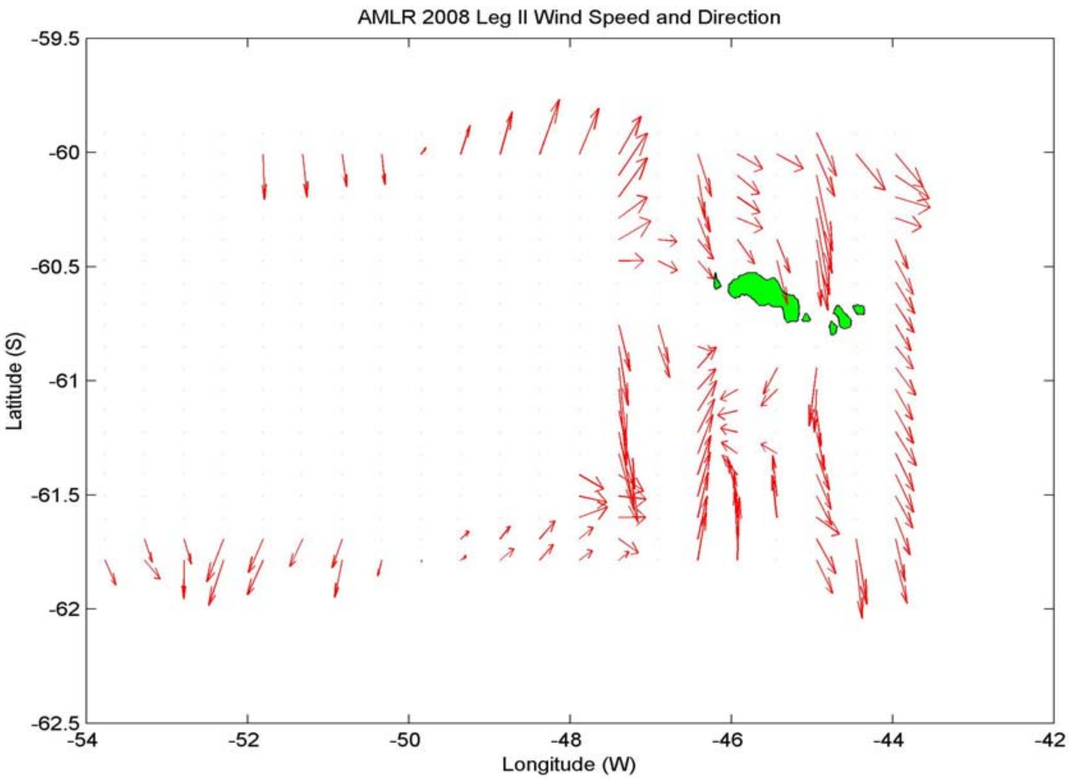


Figure 1.10. Vectors representing wind speed and direction around the South Orkney Islands (Leg II), derived from data recorded by the SCS logging system during AMLR 2007/08.

2. Phytoplankton Studies in the South Shetland Islands and South Orkney Islands Area; submitted by Christopher D. Hewes*, Brian Seegers*, Haili Wang*, Mati Kahru, B. Greg Mitchell, and Osmund Holm-Hansen (SIO), Murat V. Ardelan (Norwegian University of Science and Technolgy (Norway) and Kemal Can Bizsel*** (Institute of Marine Sciences & Technology, Dokuz Eylul University, Turkey), Maria Jose Calderón Nash* (Universidad Austral de Chile, Valdivia, Chile), Nitza Vera Santana Viviana** and José Luis Iriarte (Universidad Austral de Chile, Puerto Montt, Chile), and Nelson Silva and Cristina Carrasco*** (Escuela de Ciencias del Mar, Universidad Católica de Valparaiso, Valparaiso, Chile)**

***** Cruise participants, Leg I
** Cruise participants, Leg II
*** Cruise participants, Leg I and Leg II

2.1 Objectives: The overall objectives of our research project were to (1) assess the distribution and concentration of food reservoirs available to the herbivorous zooplankton populations in the AMLR study areas during the austral summer, and (2) compare the distribution patterns of these food reservoirs between the traditional AMLR survey area and the South Orkney Islands area.

2.2 Methods and Accomplishments: The major types of data acquired during these studies, together with an explanation of the methodology employed, are listed below. For calibration of PAR sensors, see Appendix A at the end of this report.

2.2.1 Sampling Strategy: Primary water column data were obtained from a CTD carousel, which held the water sampling bottles and various profiling sensors. The carousel was lowered to 750m depth at all deep stations and to within 10m of the bottom at the shallow stations. Profiles of the physical (salinity and temperature), optical (attenuation of solar radiation), and biological (chlorophyll-a fluorescence, 660nm transmissometer) data were recorded on the down cast. The bottles were closed on the up-cast to obtain water samples for various analyses. At the time of bottle closure, a one second binned record was obtained of all data recorded by sensors on the carousel. The same sampling protocol was used during both Legs of previous AMLR surveys. Instrumentation on the CTD carousel included:

(A) Temperature, conductivity, depth, and altimeter sensors (see Physical Oceanography, Chapter 1, for details)
(B) A Chelsea profiling fluorometer for measurement of *in situ* chlorophyll-a (Chl-a) fluorescence.
(C) Two Wet Labs profiling transmissometers for measurement of the attenuation of light at 488nm and at 660nm in the water column.
(D) Two cosine PAR (Photosynthetically Available Radiation; 400-700 nm) sensors (Biospherical Instrments QCP-200L and QCP-2300) for measurement of attenuation of solar radiation in the water column.
(E) Ten 8-liter General Oceanics Niskin bottles. Water samples at every station were obtained at 5, 10, 15, 20, 30, 40, 50, 75, 100, and 200m (or 10m above the bottom) target depths, and used for the analyses described below in Section 2.2.2

2.2.1.1 Trace Metal Clean Sampling Strategy: The phytoplankton component of AMLR this year included personnel from the Institute of Marine Sciences & Technology (Turkey) in association with the Norwegian University of Science and Technology (Norway) who measured trace element concentrations (focusing on dissolved and particulate Fe). Seawater samples were taken with pre-cleaned GO-FLO bottles (5L) mounted on 4mm Ste-Line and triggered with a Teflon-coated brass messenger at predetermined target depths of <100m . Immediately upon recovery, the GO-FLO sampler was wrapped in clean plastic bags and transferred into a HEPA-filtered forced air and plastic-lined laboratory featuring an Air Clean laminar flow hood (class 100). In the plastic-lined laboratory, an additional inline HEPA filter (HEPA VENT, 75 mm, Whatman) was attached to the air inlet of each GO-FLO sampler and a polypropylene tube with a peristaltic pump attached to the outflow valve. All tubing (tygon, polyethylene, polyproplene and PTFE), filters, and water sample bottles (Nalgene, LDPE , Fisher Scientific, 02-924-

6F 1.0L for trace metal analysis) were pre-cleaned by sequential acid solutions (3M HCL; 3M TM grade HCl; 0.1M Optima Ultra Pure HNO3). The tubing and filters were changed at every station after use, cleaned with the acid solutions, and stored in clean Ziploc plastic bags. All sample bottles were rinsed with sample water three times prior to being completely filled and stored for later analysis. For total particulate Fe samples, the sample bottles were filled without any filtration. For dissolved Fe measurements, the water was first filtered through an in-line sterile filter (a 0.4µm pore size pre filter and 0.2µm pore size filter, Sartobran-Sartorious) before filling the sample bottles. Both dissolved Fe and total particulate Fe samples were acidified to pH 1.7-1.8 with 14.7M ultra pure(UP) HNO3 (optima grade, Sigma). All sample bottles were put into Ziploc plastic bags and wrapped with a larger plastic bag for storage.

2.2.1.2 Bio-optics Sampling Strategy: During Leg I only, two specialized optical profiling units were deployed once a day near local apparent noon. These two units were (1) a free-fall profiling spectral radiometer (PRR-800, Biospherical Instruments, Inc.) to determine the spectral composition of the underwater light field and (2) a profiler to record (i) single channel spectral beam transmissometer (Wet Labs), (ii) backscattering of light (Hydroscat-6, HobiLabs), (iii) variable fluorescence (Fasttracka, Chelsea Instruments) and (iv) absorption and attenuation meter (AC9+, Wet Labs). Incident spectral irradiance (E_d, PAR) was also recorded continuously with a Biospherical QSR-240 quantum irradiance meter when the two profiling units were deployed.

2.2.2 Measurements and Data Acquired: The types of measurements and the data acquired during and in conjunction with the 2008 survey were:

(A) Chlorophyll-*a* concentrations: Chl-*a* concentrations of water samples were determined by measurement of Chl-*a* fluorescence after extraction in an organic solvent. Sample volumes of 100mL (for routine measurements) were filtered through glass fiber filters (Whatman GF/F, 25mm) at reduced pressure (maximal differential pressure of $1/3^{rd}$ atmosphere). For size-fractions of Chl-*a* containing particles, water was first gravity-filtered through polycarbonate membrane filters (2, 5, 10, and 20µm) prior to being filtered for Chl-*a*. The filters with the particulate material were placed in 10mL of absolute methanol in 15mL tubes and the photosynthetic pigments allowed to extract at 4°C for at least 12 hours. The samples were then shaken, centrifuged, and the clear supernatant poured into cuvettes (13 x 100mm) for measurement of Chl-*a* fluorescence before and after the addition of two drops of 1.0N HCl (Holm-Hansen et al., 1965; Holm-Hansen and Riemann, 1978). Fluorescence was measured using a Turner Designs Fluorometer (model TD-700) that had been calibrated using purified Chl-*a* concentrations (Sigma C-6144).

(B) Continuous profiles of Chl-*a* and PAR: Profiles of Chl-*a* obtained with the in-situ fluorometer are used in three applications: (i) to analyze Chl-*a* concentrations in relation to physical, chemical, and optical conditions in the water column, (ii) to provide a measure of physiological stress (e.g. fluorescence yield), and (iii) when combined with the profile of solar irradiance, one can estimate the rates of primary production in the water column.

(C) Beam attenuation: The attenuation of light as recorded by the transmissometer is the result of both scattering and absorption of light quanta. As the light in the transmissometer that was used is 660nm (within the red absorption band for Chl-a), the attenuation is a good indicator of both Chl-*a* concentrations and total particulate organic carbon (Villafañe et al., 1993). Data from the tranmissometer is particularly useful in estimating Chl-*a* concentrations in the upper 10-15 m of the water column where Chl-*a* fluorescence is severely inhibited by high solar irradiance (Holm-Hansen et al., 2000).

(D) Water Column Trace Metal Concentrations: Uncontaminated water samples for trace metal analysis were obtained from water bottles strung on polyester line that was spooled onto an alternate winch. Samples were collected at 17 stations from predetermined depths for iron and other trace metal determination of both dissolved and total acid leachable states (Leg I, Fig. 2.1A; Leg II, Fig. 2.2D). These water samples are used for the following measurements: (i) Total and acid leachable iron (and other trace metals) will be determined by ICP-MS after pre-concentration; (ii) Total and dissolved iron will be measured on aliquots of the same samples by FIA-Chemoluminesence; (iii) Aliquots of the water samples were frozen and will be analyzed for organic ligand and labile iron by competitive ligand exchange-cathodic striping voltametry (CLE-CSV). Details of the method used can be found in the work by Öztürk (1995) and Öztürk et al. (2002).

(E) Phytoplankton taxonomy: Seawater samples (100 mL) were obtained within the upper mixed layer and preserved with 0.5% (final dilution) buffered formalin at 27 stations in Leg I (Fig. 2.1B) and 74 stations in Leg II (Fig. 2.2B), These samples were delivered to J. L. Iriarte (Universidad Austral de Chile, Puerto Montt, Chile) for taxonomic analysis of phytoplankton species.

(F) Size-classed Chl-*a* concentrations:Water samples from 15m were processed to determine size-class spectrum for Chl-*a* concentrations at 15 stations in Leg I (Fig. 2.1C) and 25 stations in Leg II (Fig. 2.2C).

(G) Inorganic macronutrient concentrations: Water samples were taken for measurement of macronutrient concentrations at 10, 30, 50, 75, 100, and 200m target depths, poured into acid-washed 120mL polypropylene bottles and immediately frozen. In addition to these routine samples, additional samples were taken at 15 m depth at 10 stations in Leg I (Fig. 2.1D) and at 61 stations in Leg II (Fig. 2.2A). All frozen samples were delivered to N. Silva (Universidad Católica de Valparaiso, Valparaiso, Chile) to be analyzed by auto-analyzer for nitrate, phosphate, and silicate concentrations (Atlas et al., 1971).

(H) Incident Light Intensity: A Biospherical Instruments scalar PAR sensor (BSI model QSR-2100) and a LI-COR cosine PAR sensor (LI-COR model LI-190) were used to measure incident light continuously over a 24-hour period. Our cosine profiling PAR sensors were inter-calibrated with the LI-COR sensor (see Physical Oceanography, Chapter 1) so that we were able to measure euphotic zone depth (1% isolume for in situ to incident surface PAR) for daytime CTD casts.

(I) Photosynthetic pigments: Water samples from 15 stations (only in Leg I; Fig. 2.1C) for pigment determination were filtered through glass fiber filters (GF/F), the filters frozen in liquid nitrogen, and returned to SIO for analysis with high pressure liquid chromatography (HPLC) techniques using established methods (Wright et al., 1991; Goericke and Repeta, 1993; Trees et al., 2000). A total of 242 HPLC pigment samples were collected.

(J) Short-term photosynthesis-irradiance (P vs. E) response : Natural populations from 15 stations (only in Leg I; Fig. 2.1C) were incubated with ^{14}C sodium bicarbonate in vials for 1-2 hours in a light gradient ranging from 0-2000 μEinst m^{-2} sec^{-1} using a photosynthetron (Lewis and Smith, 1983). Photosynthetic efficiency, functional absorption cross-section, and turnover time of photosystem-II on these samples were assessed using fast repetition rate fluorometry (Kolber and Falkowski, 1998).

(K) Particle and soluble absorption: Absorption spectra from 300 to 800nm of total particulate matter (concentrated on a Whatman GF/F filter) and dissolved substances from 15 stations (only in Leg I; Fig. 2.1C) were measured using a double beam Cary 1E spectrophotometer (Mitchell and Kiefer, 1984; Mitchell, 1990). The filtrate, which had passed through the GF/F filter, was used to determine the spectra for dissolved substances. Absorption spectra for total particulate matter and for detritus were determined directly on the filter before and after methanol extraction as described by Kishino et al., (1985) and Sosik and Mitchell (1995).

(L) Particulate Organic Carbon and Nitrogen (POC/PON): Water samples from 15 stations (only in Leg I; Fig. 2.1C) were filtered through pre-combusted glass fiber filters (Whatman GF/F, 25mm), dried, and returned to SIO for analysis of POC and PON by gas chromatographic techniques.

(M) Size distribution of particles: Size distribution of particles from 2 to 64µm in water samples from 15 stations (only in Leg I; Fig. 2.1C) were measured using a Multisizer II Beckman Coulter Counter.

(N) Underwater light regime: An Integrated Optics Package (IOP) and a Profiling Reflectance Radiometer system (PRR) were deployed at a total of 15 mid-day CTD stations (only in Leg I; Fig. 2.1C). Data sets of 14 IOP casts and 41 PRR800 casts were acquired. Complementary water samples were taken at 16 mid-day stations for the following measurements: (i) two depths at each station for P vs. E experiments; (ii) 77 depths for (a) analysis of spectral absorption coefficients of particles (ap), detritus (ad), and soluble fraction (as), (b) measurement of particle number and size distribution, (c) POC/PON and HPLC pigments, and (d) 165 HPLC pigment samples from 10 and 75 m. The reference sensor (PRR-810) of the reflectance radiometer system continuously recorded surface downwelling irradiance at 19 spectral channels including surface incident PAR throughout the survey.

(O) Fluorescence Yield: Fluorescence Yield was estimated from voltage output of the Chelsea AquaTrak III fluorometer and Chl-*a* concentration. To maintain consistency with historical data, the Chelsea fluorometer (log) output was transformed to linear values of the previous SeaTek fluorometer (in service 1990 - 2005) using the equation:

$$\text{SeaTek Volts} = 0.0207 \cdot \exp(2.1994 \cdot \text{Chelsea Voltage}),$$

as described previously (Hewes et al., 2006). Fluorescence yield was calculated by means for the UML as:

$$\log(mV_{SeaTek}) / \log(\text{Chl-a} \cdot 1000).$$

(P) Estimation of upper mixed layer (UML) depth: Depth of the UML (Z_{UML}) was calculated as the depth at which potential density (σ_t) differed by 0.05 Kg m^{-3} from the mean potential density measured between 5 and 10 m depth.

2.3 Results and Preliminary Conclusions:

2.3.1 Phytoplankton Distribution in Surface Waters: Surface Chl-*a* concentrations during the month of January of 2008 for the areas covered by both Legs I and II are shown in the MODIS-Aqua satellite map in Fig. 2.3. During the first half of January (Fig. 2.3A), Chl-*a* concentrations were high (>0.5 mg m^{-3}) in the waters surrounding the South Shetland Islands and extending into the Elephant Island (EI) Area and southwestern Scotia Sea region. Highest phytoplankton biomass concentrations (>1.5 mg Chl-*a* m^{-3}) were found in Bransfield Strait and in two areas to the northwest of the South Orkney Islands (SOI). Sea ice and clouds prevented any satellite imagery of the sampling grid around the SOI. By the second half of January (Fig. 2.3B), and corresponding in time with the bulk of the AMLR survey work during Leg I, the high Chl-*a* concentrations in Bransfield Strait and the Scotia Sea had diminished considerably. Similarly, the plume of enhanced biomass around EI as well as that to the northwest of EI and to the east of the Shackleton Transverse Ridge also appeared to decrease significantly. Stations with the lowest surface Chl-*a* concentrations (<0.2 mg m^{-3}) were found in pelagic Drake Passage waters in the northern portions of the sampling grid and also in the eastern and southern regions where the water is mainly of Weddell Sea origin (Fig. 2.3). As sea ice and clouds prevented obtaining any satellite Chl-*a* imagery of surface waters over most of the sampling grid for Leg II, Chl-*a* concentrations in the upper mixed layer (UML) during Leg II are reported as the mean in the UML.

The mean Chl-*a* concentrations averaged for the upper mixed layer in these four areas, together with the long-term mean from previous AMLR seasons (1990-2007), are summarized in Table 2.1. Mean Chl-*a* concentrations in the UML during Leg I were lowest (~0.7mg m^{-3}) in the EI and WA and comparable to the values for the EI and SO regions in Leg II (Table 2.1 and Figs. 2.4A and **2.5A**). Highest mean values (1.0mg Chl-*a* m^{-3}) were in the JI and SA regions during Leg I. Surface Chl-*a* values were generally slightly less than the historical mean values (Table 2.1). The Joinville Island (JI) Area, however, had a higher mean Chl-*a* value than the historical mean, but station A03-14 was within an ice-mediated bloom (>2 mg Chl-*a* m^{-3}, salinities 34.34 at -0.8°C), which biased this mean. During Leg II the distribution of phytoplankton showed extremes from low to high concentrations of Chl-*a* around the South Orkney Islands and in the Elephant Island and South Areas (**Fig. 2.5A**). For the South Orkney Islands, lowest biomass was found over the southern and southeastern shelf, while highest concentrations were found offshore of the northern shelf. In the Elephant Island Area, lowest biomass was found in the northwestern quadrant, an area reported in past years as containing iron-poor Antarctic Circumpolar Current waters, with highest biomass found in the north eastern quadrant, an area reported in past years as associated with an eddy of potentially iron-rich coastal waters (Helbling et al., 1993; Hewes et al., 2003, 2005, 2008; Holm-Hansen and Hewes, 2004). Lowest biomass in the South Area was found along the Antarctic Peninsula, whereas the highest phytoplankton concentration was found along the southern coastline of the South Shetland Islands.

2.3.2 Distribution of phytoplankton in the upper water column relative to physical, chemical, and optical conditions: Variability in Chl-*a* concentrations in the water column is partially explained by the depth of the UML. Deep mixing of presumably iron-rich waters along the peninsular coast and around Elephant Island are associated with low biomass, but around the South Orkney Islands low Chl-*a* concentrations were found over the southern shelf, which had some of the shallower UML depths recorded during the survey (Table 2.1, Fig. 2.5B). The mean depths of the UML in the four areas of the routine AMLR sampling grid ranged from 57 to 135m, which were considerably deeper than that in the 37m UML depth in the SO region during Leg II (Table 2.1). There was, however, much variability in UML depths at stations within each region as shown by the data in Figs. 2.4C and 2.5B. All areas in both Legs had colder and saltier surface waters than normal, and, with the exception of the JI Area in Leg I, also had deeper than average depths for the upper mixed layer. The integrated Chl-*a* values over the depth of the UML accounted for >80% of the Chl-*a* integrated to 100m depth, with the exception of the SO area where Chl-*a* below the upper mixed layer accounted for 48% of the integrated Chl-*a* value. These physical and biological data suggest that the outflow from the Weddell Sea was stronger in 2008 than past years' average outflow.

2.3.2.1 Upper Mixed Layer Depth (Zuml) and Euphotic Zone Depth (Zeu): The effect of varying Chl-*a* concentrations on attenuation of solar radiation in the water column is shown by the data in Fig. 2.6. The ratio of euphotic zone depth to UML (Zeu:Zuml) can be used as an index of the capacity for the water column to support high potential rates of photosynthesis in nutrient-rich environments. For reference, Zeu:Zuml >1.0 would represent near to maximal capacity of photosynthesis in the UML. If the ratio of Zeu:Zuml is considerably less than 1.0, the photosynthetic rate per unit of Chl-*a* in the UML would be expected to be light-limited. Our data show that around Elephant Island and along the peninsular coast, low Zeu:Zuml values (Fig 2.5D) were associated with low Chl-*a* (Fig. 2.5A) and deep UML depths (Fig. 2.2B). However, the low biomass areas over the southern South Orkney Island shelf had high Zeu:Zuml values, suggesting that light limitation was not the primary cause of the low Chl-a concentrations.

2.3.2.2 Bio-optical data from the upper water column: The bio-optical characteristics of the phytoplankton assemblages are very different in pelagic Drake Passage waters as compared to the Chl-*a* richer shelf waters as shown by the data in Fig. 2.7. The spectral absorption curves for the two stations are quite similar in the visible region of the spectrum (400-700nm) except for the absolute values, but the ACC waters show very high absorption in the 300-350nm spectral region as compared to shelf-break waters (Fig. 2.7A). The differences between the two stations in the upper 140m of the water column are also pronounced for concentrations and distribution patterns for Chl-*a*, beam attenuation (note change of scales on the X-axis), and attenuation of solar radiation with depth (Figs. 2.7B-D, respectively). The occurrence of a deep Chl-*a* maximum at depths of 60-100m is evident in these three figures, as has been reported for all Fe-limited pelagic waters in the Southern Ocean (Holm-Hansen and Hewes, 2004). The size distribution of cells at these two stations also differed markedly as shown by the data in Fig. 2.7E.

Shelf break waters showed two major peaks of cells with sizes at ~3.5 and 9.0um, whereas the sample from ACC waters showed an increase of larger cells with sizes between 10 and 50um (Fig. 2.7E).

2.3.2.3 Chlorophyll-a concentration in relation to salinity, mixing depth, and fluorescence yield: It has recently been shown within the AMLR sampling grid that co-limiting control by UML depth and iron concentration over phytoplankton biomass can be monitored in relation to salinity (Hewes et al., 2008). Maximal Chl-*a* concentrations occur at salinities ~34; optimal conditions for bloom development existed around the South Shetland Islands and in the Elephant Island Area from the horizontal mixing between surface waters of the Weddell Sea Shelf waters (salinities ~34.4) and iron-poor Drake Passage Antarctic Surface water (salinities ~33.7). Low Chl-*a* concentrations (Fig. 2.4A) are found in Drake Passage waters, which have low salinities (<34.0; Fig. 2.4B), and shallow UML depths (Fig. 2.4C). With reference to the historical mean (1990-2007), the 2008 AMLR survey encountered deeper than average depths of surface water mixing (Fig. 2.4 D) and lower Chl-*a* concentrations (Fig. 2.4B) for Drake Passage waters. However, both the West Area and the Elephant Island Area were cooler and had higher salinity water than average (Table 2.1). In contrast, iron-rich Weddell Sea Shelf Waters (salinity 34.3-34.4) in the southeastern portion of the AMLR survey grid had relatively normal Chl-*a* concentrations (Fig. 2.4B) in spite of the fact that the depths found for the UML were deeper than average (Fig. 2.4D). These data suggest that Weddell Sea source waters, and associated biological relationships, intruded further into the AMLR survey area this season than on average.

Importantly, the greatest deviation in phytoplankton biomass during 2008 as compared to the long-term mean occurred at salinities less than ~33.95 (Fig. 2.4B). Fluorescence yield, a measure of physiological stress (Beardall et al., 2001), on average has a sharp increase with decreasing salinities less than 34.0, and corresponds with increasing influence of iron-poor Drake Passage Antarctic Surface Water (Holm-Hansen et al., 2000; Hopkinson et al., 2007). Values for 2008 indicated higher values in pelagic Drake Passage waters than the historical mean (Fig. 2.4F). These fluorescence data suggest that at salinities 33.8 – 33.9, phytoplankton populations were experiencing photo-physiological stress greater than average, possibly a result of low ambient iron concentrations. Alternatively, if deeper mixing depths (Fig. 2.4D) were the reason for the lower than average phytoplankton biomass in 2008, this would be reflected in lower than average light regimes in the UML. This hypothesis can be examined by the relationship between euphotic zone depth and UML depth. For 2008, the ratio Zeu/Zuml had lowest values in the southeastern portion and highest values in the northwestern portion of the AMLR survey area (Fig. 2.4G). As the ratios of Zeu/Zuml in 2008 for the low salinity waters were not significantly lower than the long term mean (Fig. 2.4H), it seems unlikely that low light regimes in the UML were responsible for the low Chl-*a* concentrations in these waters in 2008.

2.3.2.4 Horizontal Distribution of Chlorophyll-a Concentration in relation to Hydrography: The regions surveyed for the IPY portion of the AMLR 2008 program are each diverse in their hydrographic and photo-biological characteristics (Fig. 2.5), although all have similar phytoplankton biomass (Table 2.1). Bransfield Strait (Fig. 2.8A-G) can be characterized as having small differences between surface and deeper water densities (Fig. 2.8A), being composed of cold (Fig. 2.8B), saline (Fig. 2.8C) surface waters. For the three representative stations, temperature/salinity profiles (Fig. 2.8D) indicate very different compositions in the surface water, yet phytoplankton biomass (Fig. 2.8F, G) ranged from 0.4 to 1.2mg Chl-*a* m^{-3} with magnitude in concentration a function of UML depth. The lowest phytoplankton biomass (green lines; Fig. 2.8F, G) was associated with a deeply mixed UML to ~200 m (Fig. 2.8A-C), whereas the other stations plotted clearly indicate biomass following contours of surface mixing with depth. This is contrasted with three stations representing pelagic Antarctic Circumpolar Current waters (Fig. 2.8L), which were well stratified, with UML depths ~50 m (Fig. 2.8H-J) that lay over the winter water remnants from the previous years deep mixing (Fig. 2.8K). Phytoplankton biomass in these surface waters varies both as a function of UML depth and iron (Helbling et al., 1991; Holm-Hansen et al., 1997; Holm-Hansen and Hewes, 2004; Hopkinson et al., 2007; Hewes et al., 2008). In the Drake Passage (blue symbol and lines), surface waters are limited by iron (presumably indicated by high fluorescence yields, Fig. 2.5C), while just below the pycnocline in the winter-water remnant, a deep Chl-*a* maximum occurs

(Fig. 2.8M, N), being within the bottom of the euphotic zone (Fig. 2.6) and having elevated concentrations of iron. The other two stations shown for this area (red and green lines) have much higher biomasses, presumably because iron is present to support it (Fig. 2.5C), and the profiles of this biomass with depth follow their respective contours of density. The South Orkney (SO) Island region had a less saline, less dense, and colder surface layer (Fig. 2.8O-Q) leading to a reduction in UML depth compared with the other two regions. This surface layer overlays the colder winter water remnant of Weddell Sea Water lying at ~75m. Of interest, however, is that for these stations with low biomass in the UML (green lines, Fig. 2.8T,U), there is sufficient PAR (Fig. 2.6) below the pycnocline that could support elevated rates of photosynthesis. There was a pronounced deep Chl-*a* maximum as found in Drake Passage ACC waters in the southeastern portion of the SO, and high Chl-*a* values down to 100m in the southwestern portion (Fig. 2.8U). The two most likely explanations for these Chl-*a* distributions with depth are (i) that iron is limiting in these waters (samples yet to be processed in Norway), or (ii) that it is related to degree of turbulent mixing (Huisman et al., 1999; 2006).

2.4 General Conclusions from the AMLR 2008 Field Season. Our data indicate that this season had cooler and saltier surface waters, likely linked to an increased Weddell Sea outflow into the Bransfield Strait and surroundings, leading to deepened surface water mixing. Although UML depths were deeper than normal at salinities >34.2 (Joinville Island Area), these did not reduce Chl-*a* concentrations significantly because biomass is normally low as associated with deep mixing regimes. Surface mixing depths were also about average at intermediate salinities of ~34, as were Chl-*a* concentrations at those depths. Therefore, phytoplankton biomass followed similar trends to previous years for salinities >34, incorporating the South Area and Joinville Island Area. However, differences in phytoplankton biomass for 2008 were found at salinities <34.9, below which Chl-*a* concentrations were much lower than normal and associated with a deeper UML and higher fluorescence yield than the 18-year mean. The high fluorescence yields for these low-salinity stations suggest an onset of nutrient (iron) stress, which is compatible with the idea that blooming tended to end early for this season – the peak biomass usually occurs in mid-February. The bio-optical data also demonstrated the dramatic differences between the low-salinity, low-Fe Drake Passage waters and shelf-break waters in regard to spectral absorption of the phytoplankton assemblages as well as cell size distribution. The data from the Elephant Island and South Areas during Leg II were consistent with the above statements. Our data from the South Orkney Island survey area, however, indicate that the distribution of phytoplankton in relation to hydrographic conditions are vastly different than what has been historically, and is currently, observed in the standard AMLR survey area.

2.5 Other: Samples for phytoplankton taxonomy, dissolved and particulate trace metals, particulate carbon and nitrogen, primary productivity, HPLC pigment concentrations, and macronutrients are in the process of being analyzed at the time of this report.

2.6 Disposition of the Data: All chlorophyll and CTD-interfaced sensor data obtained during these cruises have been archived with AERD, Southwest Fisheries Science Center. Other data from the cruise will be delivered to AERD when available.

2.7 Problems and Suggestions: An additional incident cosine PAR sensor attached directly to the SeaBird CTD electronics in order to measure incident PAR coincident with CTD casts would be useful. In this manner, euphotic zone depth could be measured directly during a station cast, rather than through its mathematical estimation as currently employed. A dedicated clean water system for analytical work (Alpha-Q or Milli-Q) would be an appropriate acquisition in the future, since trace-metal chemistry and salinity measurements require higher purity levels than otherwise available from the regular water supply of the R/V *Yuzhmorgeologiya*. One problem encountered with our SIO equipment was that the Chelsea FRRF and Beckman LSC did not work during the entirety of Leg I.

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2.9 References:

Atlas, E. L., L.I. Gordon, S.W. Hager, and P.K. Park. 1971. A practical manual for the use of the Technicon Autoanalyzer in seawater nutrient analyses: revised. Oregon State University, Department of Oceanography. Technical Report 71-22, 49 pp.

Beardall, J., E. Young, and S. Roberts. 2001. Approaches for determining phytoplankton nutrient limitation. Aquatic Science 63: 44-69.

Goericke, R., and D.J. Repeta. 1993. Chlorophylls a and b and divinyl chlorophylls a and b in the open subtropical North Atlantic Ocean. Mar. Ecol. Prog. Ser. 101: 307-313.

Helbling, E.W., Villafañe, V., and Holm-Hansen, O. 1991. Effect of Fe on productivity and size distribution of Antarctic phytoplankton. Limnol. Oceanogr. 36: 1879-1885.

Helbling, E.W., A.F. Amos, S.N. Silva, V.E. Villafañe, and O. Holm-Hansen. 1993. Phytoplankton distribution and abundance as related to a frontal system north of Elephant Island, Antarctica. Antarctic science 5: 25-36.

Hewes, C.D., M. Zhao, r. Dorland, B.G. Mitchell, M. Kahru, and O. Holm-Hansen. Chlorophyll-a concentrations in the upper water column of the AMLR sampling grid. 2003. In (Lipsky, J.D., ed.) AMLR 2002/2003 Field Season Report, Objectives, Accomplishments, and Tentative Conclusions. NOAA-TM-NMFS-SWFSC-355, pp. 30-41.

Hewes, C.D., N. Rojas, C. Valenzuela, B.G. Mitchell, M. Kahru, and O. Holm-Hansen. 2005. Phytoplankton Studies. In (Lipsky, J.D., ed.) AMLR 2004/2005 Field Season Report, Objectives, Accomplishments, and Tentative Conclusions. NOAA-TM-NMFS-SWFSC-385, pp. 31-46.

Hewes, C.D., N. Delany, B. Seegers, B.G. Mitchell, M. Kahru, O. Holm-Hansen, M. Özturk, H. Dulaiova, P. Henderson, M. Charette, J.L. Iriarte, and N. Silva. 2006. Phytoplankton Studies. In (Lipsky, J.D., ed.) AMLR 2005/2006 Field Season Report, Objectives, Accomplishments, and Tentative Conclusions. NOAA-TM-NMFS-SWFSC-397, pp. 31-46.

Hewes, C.D., C.S. Reiss, M. Kahru, B.G. Mitchell, and O. Holm-Hansen. 2008. Control of phytoplankton biomass by dilution and mixing depth in the western Weddell-Scotia Confluence (WSC). Mar. Ecol. Prog. Ser. *in press*.

Holm-Hansen, O., and B. Riemann. 1978. Chlorophyll a determination: Improvements in methodology. OIKOS 30: 438- 447.

Holm-Hansen, O., C.J. Lorenzen, R. W. Holmes, and J.D.H. Strickland. 1965. Fluorometric determination of chlorophyll. J. Cons. perm. int. Explor. Mer 30: 3-15.

Holm-Hansen, O., C.D. Hewes, V.E. Villafañe, E.W. Helbling, N. Silva, and A. Amos. 1997. Phytoplankton biomass and distribution in relation to water masses around Elephant Island, Antarctica. Polar Biol. 18:145-153.

Holm-Hansen, O., A.F. Amos, and C.D. Hewes. 2000. Reliability of estimating chlorophyll-a concentrations in Antarctic waters by measurement of in situ chlorophyll-a fluorescence. Mar. Ecol. Prog. Ser. 196: 103-110.

Holm-Hansen, O. and C.D. Hewes. 2004. Deep chlorophyll-a maxima (DCMs) in Antarctic waters: I. Relationships between DCMs and the physical, chemical, and optical conditions in the upper water column. Polar Biol. 27; 699-710.

Hopkinson B.M., Mitchell, B.G., Reynolds, R.A., Wang, H., Selph, K.E., Measures, C.I., Hewes, C.D., Holm-Hansen, O., and Barbeau K. 2007. Iron limitation across chlorophyll gradients in the southern

Drake Passage: phytoplankton responses to iron addition and photosynthetic indicators of iron stress. Limnol. Oceanogr. 52: 2540–2554.
Huisman, J., P. van Oostveen; F. J. Weissing. 1999. Critical Depth and Critical Turbulence: Two Different Mechanisms for the Development of Phytoplankton Blooms. Limnol. Oceanogr. 44(7): 1781-1787.
Huisman, J., N. N. P. Thi, D. M. Karl, and B. Sommeijer. 2006. Reduced mixing generates oscillations and chaos in the oceanic deep chlorophyll maximum. Nature 439:322-325 doi:10.1038/nature04245.
Kishino, M., N. Takahashi, N. Okami, and S. Ichimura. 1985. Estimation of the spectral absorption coefficients of phytoplankton in the sea. Bull. Mar. Sci., 37: 634-642.
Kolber, Z.S., and P.G. Falkowski. 1998. Measurements of variable chlorophyll fluorescence using fast repetition rate techniques: defining methodology and experimental protocols. Biochem. Biophys. Acta, 1367: 88-106.
Lewis, M.R., and J.C. Smith. 1983. A small volume, short-incubation-time method for measurement of photosynthesis as a function of incident irradiance. Mar. Ecol. Prog. Ser. 13: 99-102.
Mitchell, B.G. 1990. Algorithms for determining the absorption coefficient of aquatic particulates using the quantitative filter technique (QFT). Spinrad, R. SPIE 1990 Technical Symposium. Ocean Optics X SPIE Technical Symposium, Bellingham, Washington, 137-148.
Mitchell, B.G., and D.A. Kiefer.1984. Determination of absorption and fluorescence excitation spectra for phytoplankton. Pages 157-169, in Marine Phytoplankton and Productivity (Holm-Hansen, O., l. Bolis, and R. Gilles, eds.). Lecture Notes on Coastal and Esturaine Studies, Vol. 8. Springer-Verlag. New York.
Mitchell, B.G., and O. Holm-Hansen. 1991. Observations and modeling of the Antarctic phytoplankton crop in relation to mixing depth. Deep-Sea Res. 38: 981-1,007.
Nelson, D.M., and W.O. Smith, Jr., 1991. Sverdrup revisited: Critical depths, maximum chlorophyll levels, and the control of Southern Ocean productivity by the irradiance-mixing regime. Limnol. Oceanogr. 36: 1650-1651.
Öztürk, M., E. Steinnes, and E. Sakshaug. 2002. Iron Speciation in the Trondheim Fjord from the Perspective of Iron Limitation for Phytoplankton. Estuarine, Coastal and Shelf Science 55: 197-212.
Öztürk, M. 1995. Trends of trace metal (Mn, Fe, Co, Ni, Cu, Zn, Cd and Pb) distributions at the oxic-anoxic interface and in the sulfidic water of the Drammensfjord. Mar. Chem. 48: 329-342.
Shields, D., J. Katebini, T. Stepka, ad S. Chang. 2003. Scientific computer system (SCS) version 3.3a for Windows XP/2000/NT4.0. Office of Marine and Aviation Operations, Systems Development Office, NOAA, Silver Spring, Maryland.
Sosik, H.M., and B.G. Mitchell. 1995. Light absorption by phytoplankton, photosynthetic pigments, and detritus in the California Current System. Deep-Sea Res. I, 42: 1717-1748.
Trees, C.C., D.K. Clark, R.R. Bidigare, M.E. Ondrusek, and J.L. Mueller. 2000. Accessory pigments versus chlorophyll a concentrations within the euphotic zone: A ubiquitous relationship. Limnol. Oceanogr. 45: 1130-1143.
Villafañe, V., E.W. Helbling and O. Holm-Hansen. 1993. Phytoplankton around Elephant Island, Antarctica: distribution, biomass and composition. Polar Biol. 13: 183-191.
Wright, S. W., S.W. Jeffrey, R.F.C. Mantoura, C.A. Llewellyn, T. Björnland, D. Repeta, N. Welschmeyer. 1991. Improved HPLC method for the analysis of chlorophylls and carotenoids from marine phytoplankton. Mar. Ecol. Prog. Ser. 77: 183-196.

Appendix A: Calibration of the US AMLR Program's Photosynthetically Available Radiation (PAR) sensors; submitted by Christopher D. Hewes, Scripps Institution of Oceanography, La Jolla, California, USA

Objective: Measurement of the underwater light regime provides information on the potential for primary production in the water column. The 1% isolume of photosynthetically active radiation (PAR; 400-700 nm) is generally considered to be the approximate depth where respiration is balanced by photosynthesis. For determining the depth of the 1% isolume (Zeu), one may use 1% of solar radiation incident upon the sea surface or 1% of solar radiation immediately below the sea surface. In our studies we define it as 1% of incident solar radiation. The percentage of downwelling solar radiation which penetrates the ocean surface is affected by sun angle, atmospheric conditions (e.g., clear vs cloudy), and sea state (e.g., waves and surface roughness). Hence the depth at which the rate of photosynthesis (which is light dependent) is equal to the rate of respiration (which is not dependent upon light) will vary throughout the light day and will also be dependent upon meteorological conditions. It should be noted that that the attenuation coefficient for PAR will vary continuously with depth depending upon the concentration and characteristics of both particulate and dissolved organic matter. The attenuation coefficient for PAR will also vary with depth even if the particles and dissolved matter are homogeneously distributed in the water column, as the attenuation coefficients will vary with the changing spectral irradiance with depth. In spite of these complexities in regard to estimating the depth to which there can be net photosynthetic production of organic carbon, the conventional concept that the depth to which there can be daily net primary production is close to the 1% of incident solar radiation is a practical tool to apply in studies of organic carbon cycling in aquatic ecosystems.

During the 18 years of the US AMLR program, PAR sensors (both incident and profiling) of varying types and manufacturer have been used. However, calibration between these different light sensors was not made in the early years (1990-1993) and therefore there is some uncertainty about the consistency of the historical light data for this full 18 year period. In this report we compare the stability and calibration response of the two profiling light sensors used from 1994 to present. The overall objective of this study was therefore to inter-calibrate these two profiling PAR sensors with the primary sensor measuring incident PAR in order to have historical consistency in our estimation of euphotic zone depths, which is important in regard to our estimation of rates of primary production in the upper water column.

Calibration Method: A LI-COR cosine (2π; flat sensor) quantum sensor (LI-190, Serial No. Q28168), calibrated between AMLR cruises annually by Coastal Environmental Systems since 2000, has been mounted in a Weatherpak meteorological station affixed amid ship ~40 m above the sea surface. Cosine incident PAR (µEin m^{-2} s^{-1}) is continuously measured and is automatically logged by the Scientific Computer System (SAS) software (Shields et al., 2003), along with hydrographical, meteorological, and related ship operations data. Data are typically binned to 1-minute intervals and are placed into an integrated dataset.

Two Biospherical Inc. (BSI) cosine PAR sensors, QCP-200L (serial no. 4264; “Old BSI”) and QCP 2300 (serial no. 4744; “New BSI”) have been and are used to obtain *in situ* irradiance in the water column during CTD casts at stations that are occupied at random times of the day and night. The “Old” BSI Par sensor was used from 1994 to 2008, and the “New” BSI sensor has been used since 2007. BSI instruments record in log_{10} volts and have a log-linear conversion to obtain quanta. Thus, there are two years of overlap between each of the BSI profiling sensors, and also between the new BSI sensor and the LI-CORdeck cell. These two profiling instruments have been calibrated by BSI, but not consistently or to satisfaction. Both of these sensors are attached to a Sea Bird Electronics, Inc., conductivity-temperature-depth (SBE-911 CTD) instrument that is connected to a computer by a SBE 11 Plus CTD Deck Unit. The two disparate data streams, i.e., a continuously monitored incident irradiance and CTD mounted depth resolved water column irradiance, were multiplexed using code written by Derek Needham (STS Inc., Cape Town South Africa) to simultaneously record output from the SBE 11 Plus and the Weatherpak system. In this way, a cosine PAR sensor attached to the CTD (including hydro-wire) could be compared with the LI-COR cosine PAR sensor of the Weatherpak as logged by the SCS system. While in port (February 11-12, 2008), the LI-COR PAR sensor and the Old BSI sensor were continuously operated for 24-hours. The Old BSI PAR sensor was mounted at the stern of the ship in a shade free area. Correlations between the voltage output for the Old BSI sensor and PAR measured by the LI-COR provided calibration between these sensors. This calibration between the Old BSI sensor and the LI-COR sensor was made in air, therefore the Q2-3 Immersion Coefficient of 0.95 is applied to convert the BSI voltages to quanta in the water column. In addition, the Old BSI and the New BSI PAR sensors were operated simultaneously *in situ* during several station casts (0-750 m) of the AMLR surveys during 2007 and 2008 to determine whether instrument drift was significant between years as well as providing a correspondence between output voltages between sensors under *in situ* conditions.

Results and Preliminary Conclusions: Comparison of the voltages of the profiling PAR sensors in 2007 and 2008 showed very similar relationships between years (Fig. 1A). In fact, no significant difference was found between the New BSI and the Old BSI profiling PAR sensors, indicating stability between years. The response of the Old PAR sensor was log-linear across the range of light observed during the study period (0-1500 µE m^{-2} s^{-1}) as measured by the LI-COR sensor (Fig. 1B) that provides the proportion for inter-calibration between the two sensors as µE m^{-2} s^{-1} = 0.0616 $x10^{Volts}$ for the Old BSI PAR sensor (Fig. 1C). For the New PAR sensor, the calibration factor has the same slope, but a constant of 0.81 is applied.

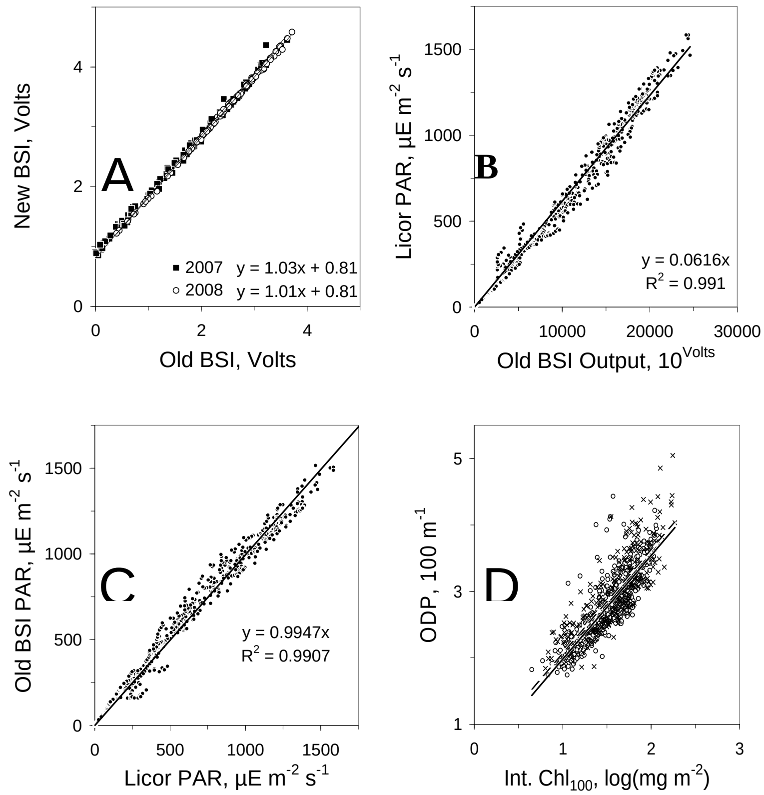

Fig. 1. Raw and processed data for inter-calibration of PAR sensors for AMLR 2008 surveys. (A) Relationship of output voltages between the New BSI PAR sensor (QCP 2300) with the Old PAR sensor during limited station casts in 2007 (solid square) and 2008 (open circles) to examine if there was significant instrument drift during the course of survey work. For graphical purposes, only 100-200 of the 1000+ data are plotted. (**B**) Output (exponential of voltage) from the Old BSI PAR sensor (QCP 200L) in relation with measured PAR from the calibrated LI-COR sensor to compute µE m^{-2} s^{-1} from the Old BSI PAR sensor. (**C**) Correspondence of µE m^{-2} s^{-1} as calculated by the Old BSI using the factor derived in (**B)** with that measured by the LI-COR PAR sensor. For **A**-**C**, regression and/or r^2 for regression lines as plotted. (**D**) Scalar (1994-1999; 'X's) and cosine (2001-2007; circles) incident PAR derived values of optical density equivalent (ODP) for 725 station data in relation to Chl-a integrated to 100 m (CHL_{100}). A bend from linearity is found at surface concentrations of ~0.5 mg Chl-a m^{-2}, and are best described by cosine (dashed line) and scalar (solid line) vs. log transformed integrated Chl-a concentrations.

For years 1994-1999, a scalar (4π; "golf ball") PAR sensor (Biospherical Instruments QSR-240) was mounted in a shade-free, low reflectance area of an upper deck to measure incident PAR, being different than the LI-COR used 2000-present. Beers Law, which describes the relationship between the concentration of a substance for a fixed pathlength and the attenuation of monochromatic light, is used to examine the consistency of calibrations used for both incident and water column PAR sensors among years (1993-2008) for data contained in the AMLR database. The attenuation of PAR by Chl-a in the water column for a fixed depth should behave similarly, since the absorption of PAR by water can be considered relatively constant if sampled under similar chemical and physical conditions. An optical density equivalent using PAR (ODP) was obtained by negative log (base 10) transformation of *in situ* PAR at 100 m per incident PAR (measured during water bottle sampling). Data were restricted to those obtained 95-100 m and within 11:00-21:00 hrs GMT (local noon is 16:00 GMT). Within these criteria, 330 station data occurred for 1994-1999 and 395 station data occurred for 2001-2007. Chl-a concentrations measured for these stations were integrated to 100 m by standard protocol. The ODP for both scalar and cosine incident PAR have a relationship that bends slightly at ~50 mg Chl-a m^{-2} (Fig. 1D). Importantly, no difference in ODP vs. Chl-a occurred among years (ANOVA; n=725, $p <$ 0.001) indicating that factors used for converting voltages from all sensors into units of PAR as applied in the AMLR database are reasonable.

Table 2.1. Mean chlorophyll-a concentrations in the upper mixed layer (UML) and when integrated to 100m depth in the five survey areas in relation to (i) the depth of the UML, (ii) the depth of the euphotic zone, and (iii) the means (with standard deviation) in the UML for temperature, salinity, and density. Data from Leg I and II are shown in separate sections, which also include the mean values for 18 years, 1990-2007. The number of stations in each area is indicated by N, with the number in parentheses showing the number of daytime stations where euphotic zone depth could be measured. The four survey areas in the routine AMLR studies are Elephant Island (EI) Area, Joinville Island (JI) Area, South Area (SA), West Area (WA); these areas are shown in Figure 2 in the Introduction of this report. The region covered by the South Orkney Islands (SO) is shown in Fig. 2.5.

Leg	Area	N	Zuml, m	Zeu, m	Temperature, °C	Salinity	Density, kg m^{-3}	Chl-a, mg m^{-3}	Chl-a (100 m), mg m^{-2}
I	2008								
	EI	46 (5)	74 ± 37	47 ± 3	0.93 ± 0.58	34.12 ± 0.17	27.34 ± 0.17	0.7 ± 0.5	59 ± 36
	JI	10 (8)	135 ± 68	49 ± 10	-0.48 ± 0.75	34.34 ± 0.07	27.59 ± 0.09	1.0 ± 0.6	85 ± 44
	SA	19 (15)	62 ± 45	43 ± 10	0.63 ± 0.94	34.22 ± 0.12	27.43 ± 0.15	1.0 ± 0.4	63 ± 18
	WA	27 (20)	57 ± 22	65 ± 20	1.09 ± 0.42	34.06 ± 0.18	27.28 ± 0.16	0.6 ± 0.6	43 ± 31
	1990-2007								
	EI	879	55 ± 32		1.47 ± 0.82	34.02 ± 0.20	27.19 ± 0.2	0.8 ± 0.8	54 ± 41
	JI	41	83 ± 56		0.28 ± 0.86	34.30 ± 0.13	27.46 ± 0.13	0.7 ± 0.5	52 ± 27
	SA	190	48 ± 43		1.15 ± 0.84	34.15 ± 0.18	27.31 ± 0.15	1.2 ± 0.9	68 ± 38
	WA	261	49 ± 20		1.56 ± 0.71	33.94 ± 0.16	27.11 ± 0.15	0.7 ± 0.8	47 ± 35
II	2008								
	EI	44 (26)	70 ± 36	54 ± 15	1.4 ± 0.7	34.10 ± 0.17	27.30 ± 0.18	0.7 ± 0.4	51 ± 24
	SA	21 (12)	75 ± 65	46 ± 11	0.6 ± 0.9	34.20 ± 0.14	27.42 ± 0.16	0.8 ± 0.3	58 ± 17
	SO	48 (30)	37 ± 14	54 ± 13	0.2 ± 0.5	33.57 ± 0.32	26.94 ± 0.25	0.7 ± 0.4	50 ± 21
	1990 -2007								
	EI	838	58 ± 28		1.59 ± 0.81	34.00 ± 0.20	27.20 ± 0.21	0.9 ± 1.0	62 ± 56
	SA	150	55 ± 23		1.12 ± 0.65	34.14 ± 0.14	27.34 ± 0.14	1.4 ± 1.7	87 ± 92

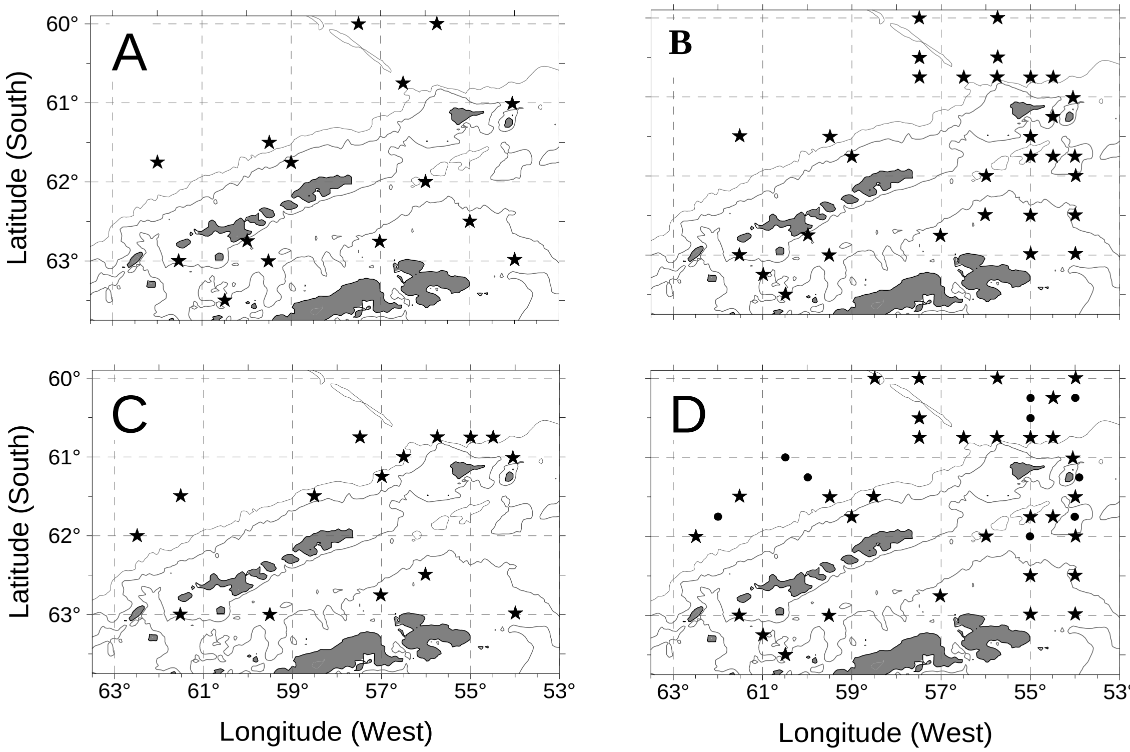

Fig. 2.1. Location of stations during Leg I where samples were taken for iron (**A**), floristic analysis (**B**), HPLC pigments, P vs. E, POC/PON, size-classed Chl-a, and coulter counter analyses as well as IOP casts (**C**), and macronutrients (**D**). Macronutrients were sampled at 10, 30, 50, 75, 100, and 200 meters (star) or just in the upper mixed layer (filled circle). At the stations shown by a filled circle, one sample was also obtained for Fe analysis.

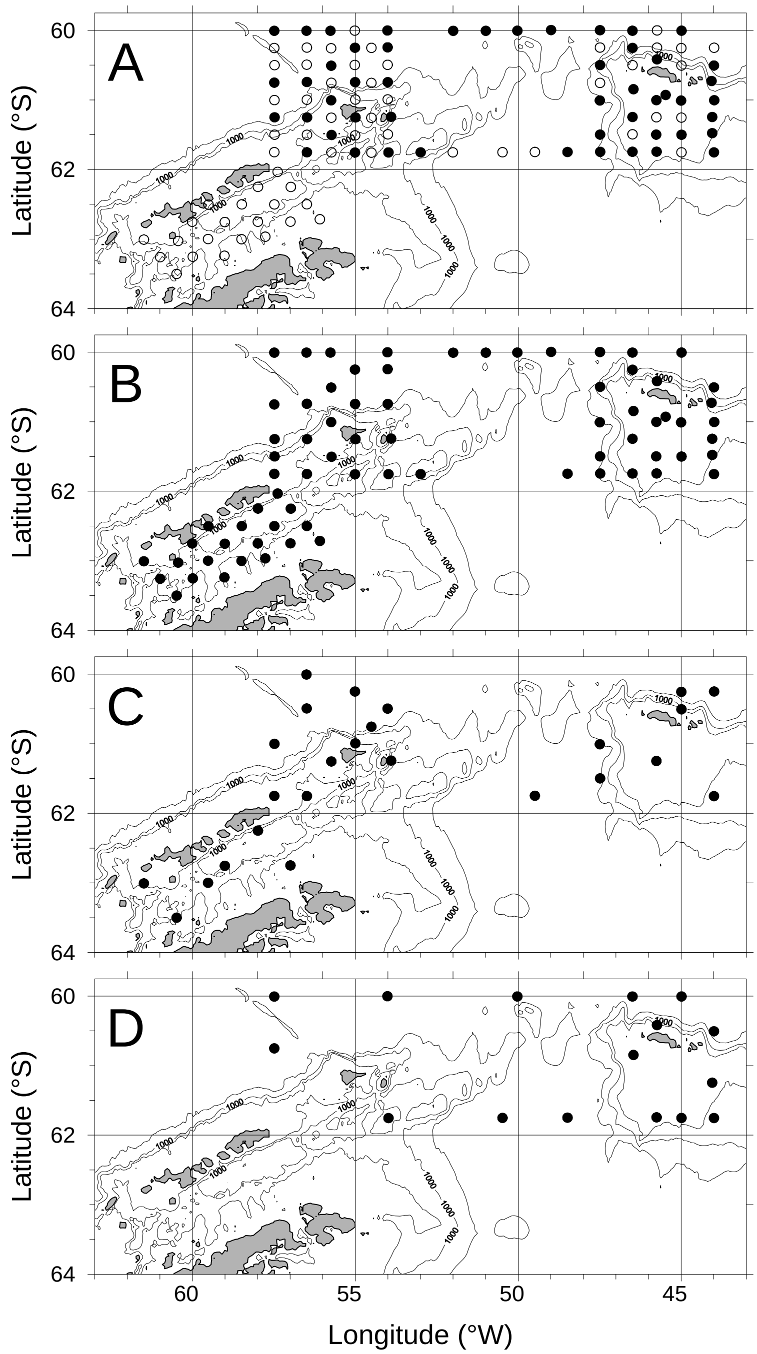

Fig. 2.2. Station locations during Leg II. **(A)** Locations where macronutrients (silicate, nitrate and phosphate) were sampled at depths of 10, 30, 50, 75, 100, and 200 m (solid circles) or at 15 m (open circles). (**B**) Locations where water samples collected from 15 m were preserved with 1% buffered formalin (final dilution). (**C**) Locations of where 15 m water was collected for size-fractions of Chl-a using 2, 5, 10, and 20 µm polycarbonate membrane filters. (**D**) Locations of stations in which samples for dissolved and particulate trace-metals were collected.

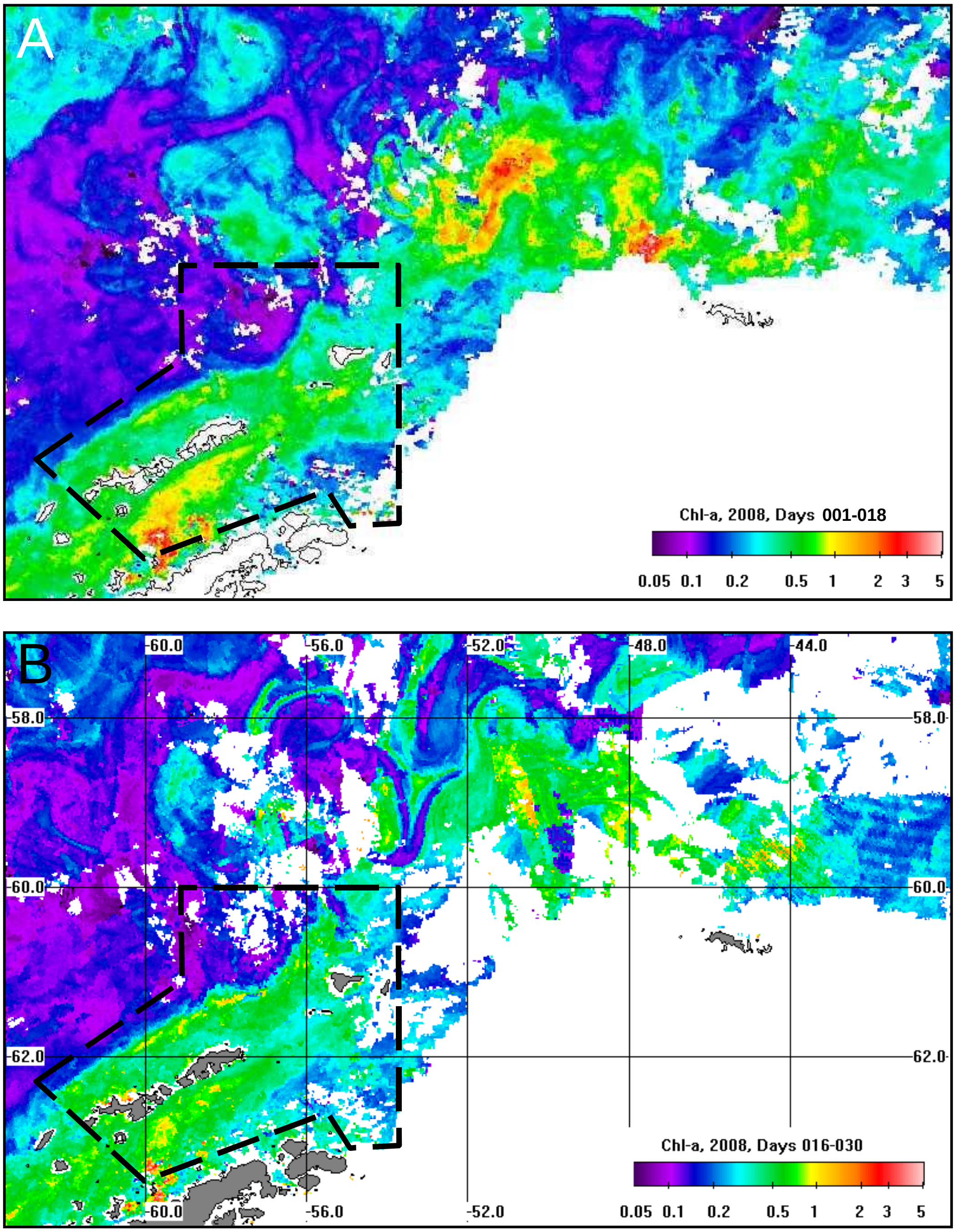

Fig. 2.3. MODIS-Aqua satellite derived Chl-a distributions for January 1-18 (**A**) and January 16-30 (**B**), 2008, in the Drake Passage and southwestern Scotia Sea region. The approximate AMLR survey grid area for Leg I is shown enclosed with dashed lines.

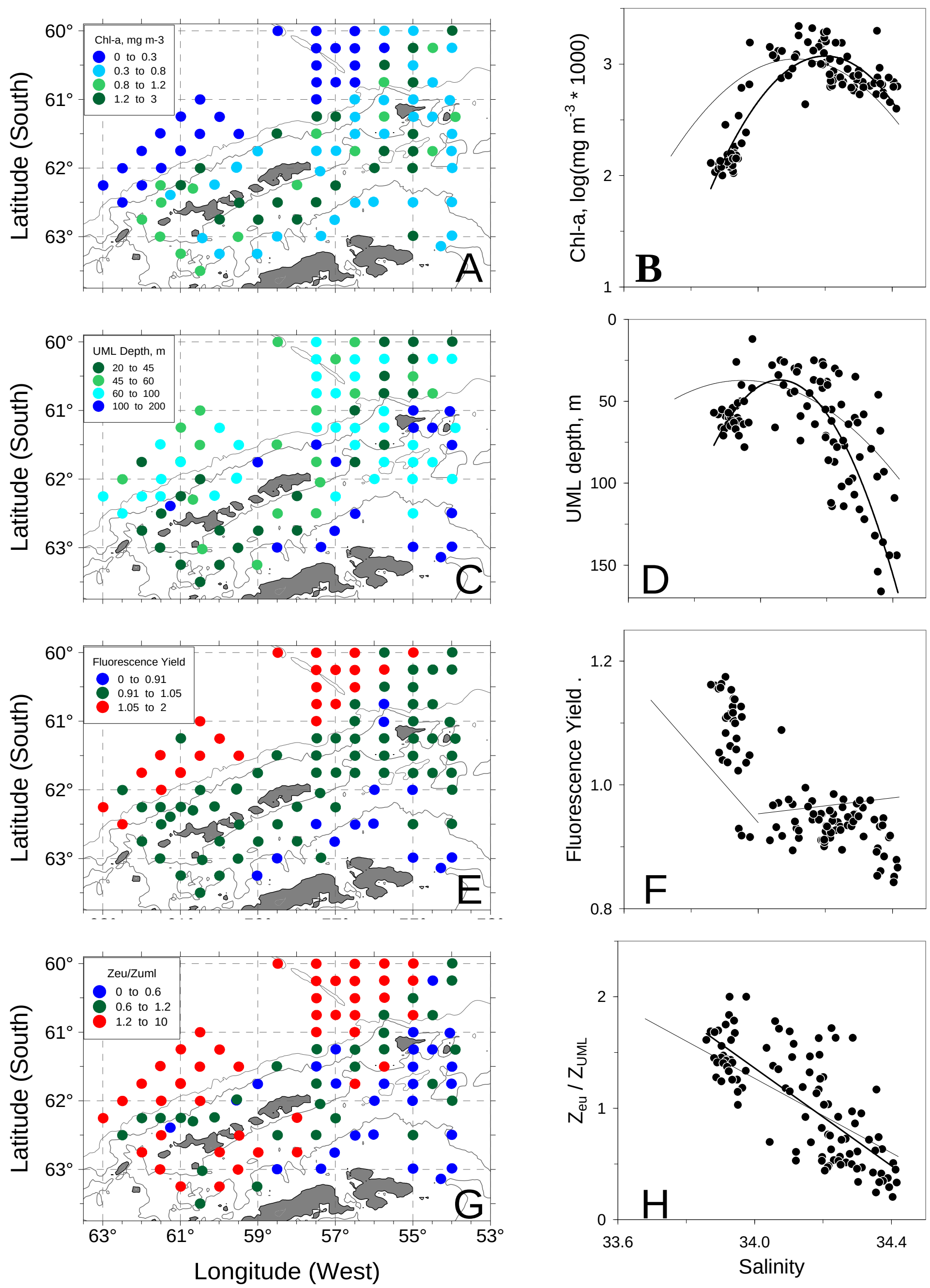

Fig. 2.4. Water column characteristics during Leg I (**A**, **C**, **E**, **G**) and when the values are expressed against the salinity gradient (**B**, **D**, **F**, **H**; the heavy dark line is the 2nd-order polynomial regression for the 2008 season and the light line is the 18-year mean). (**A**) Concentrations of the mean Chl-a values in the UML and when the Chl-a values are shown across the salinity gradient (**B**). (**C**) UML depths in the AMLR survey area and when the values are expressed against the salinity gradient (**D**). (**E**) The mean fluorescence yield at each station and when the values are expressed against the salinity gradient (**F**). (**G**) Zeu/Zuml values at each station and when the values are expressed against the salinity gradient (**H**).

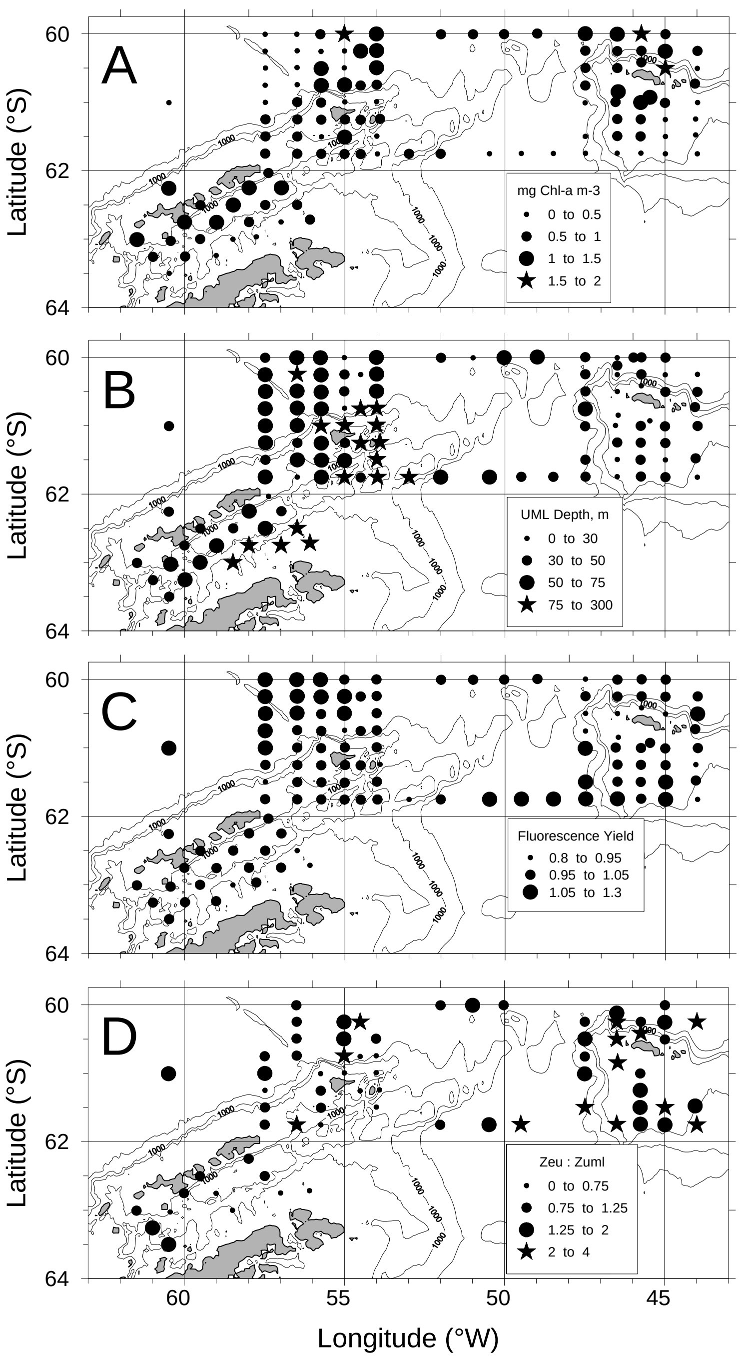

Fig. 2.5. Water column characteristics during Leg II. (**A**) Mean concentrations of the Chl-a values in the UML. (**B**) Depth of the UML. (**C**) Mean fluorescence yield in the UML. (**D**) The ratio of euphotic zone depth to UML depth (Zeu:Zuml) at each station.

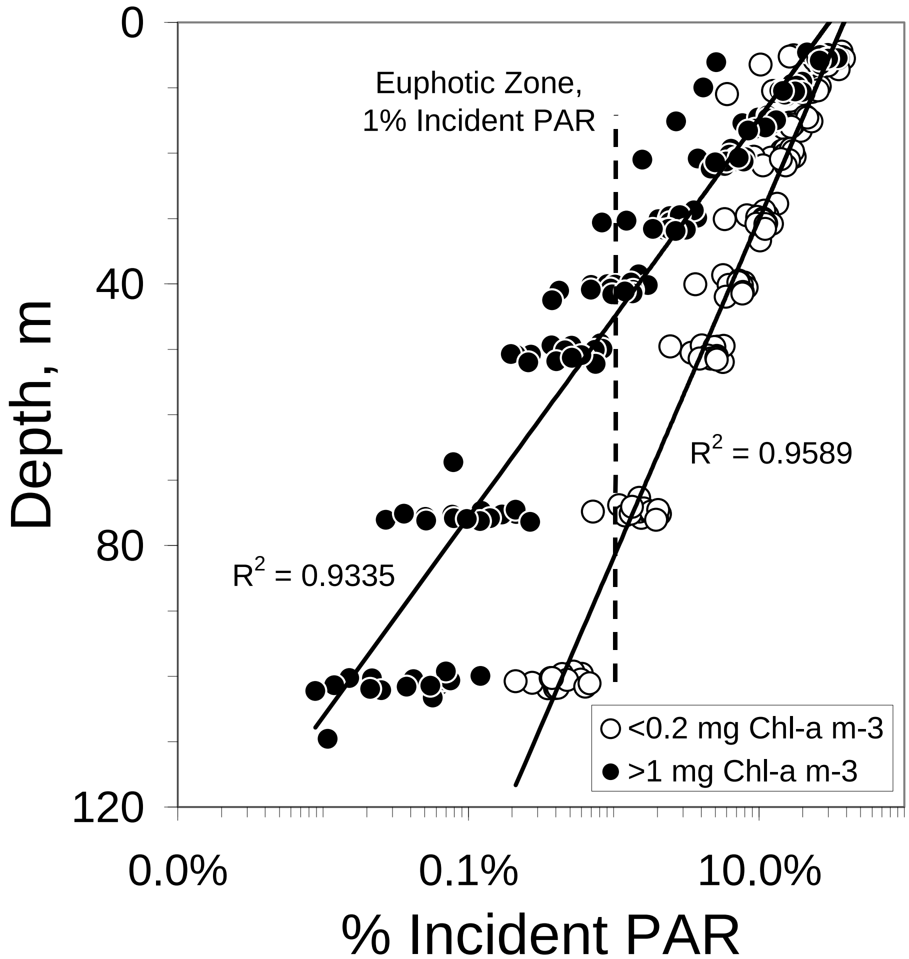

Fig.2.6. Relationship of euphotic zone depth to Chl-a concentration. Percent of in situ Photosynthetically Available Radiation (PAR, from binned bottle data) to incident PAR in relation to mean UML Chl-a concentrations of <0.2 (open circles) and >1.0 (filled circles) mg m^{-3}. Euphotic zone (1% of incident PAR) is shown by the dashed line.

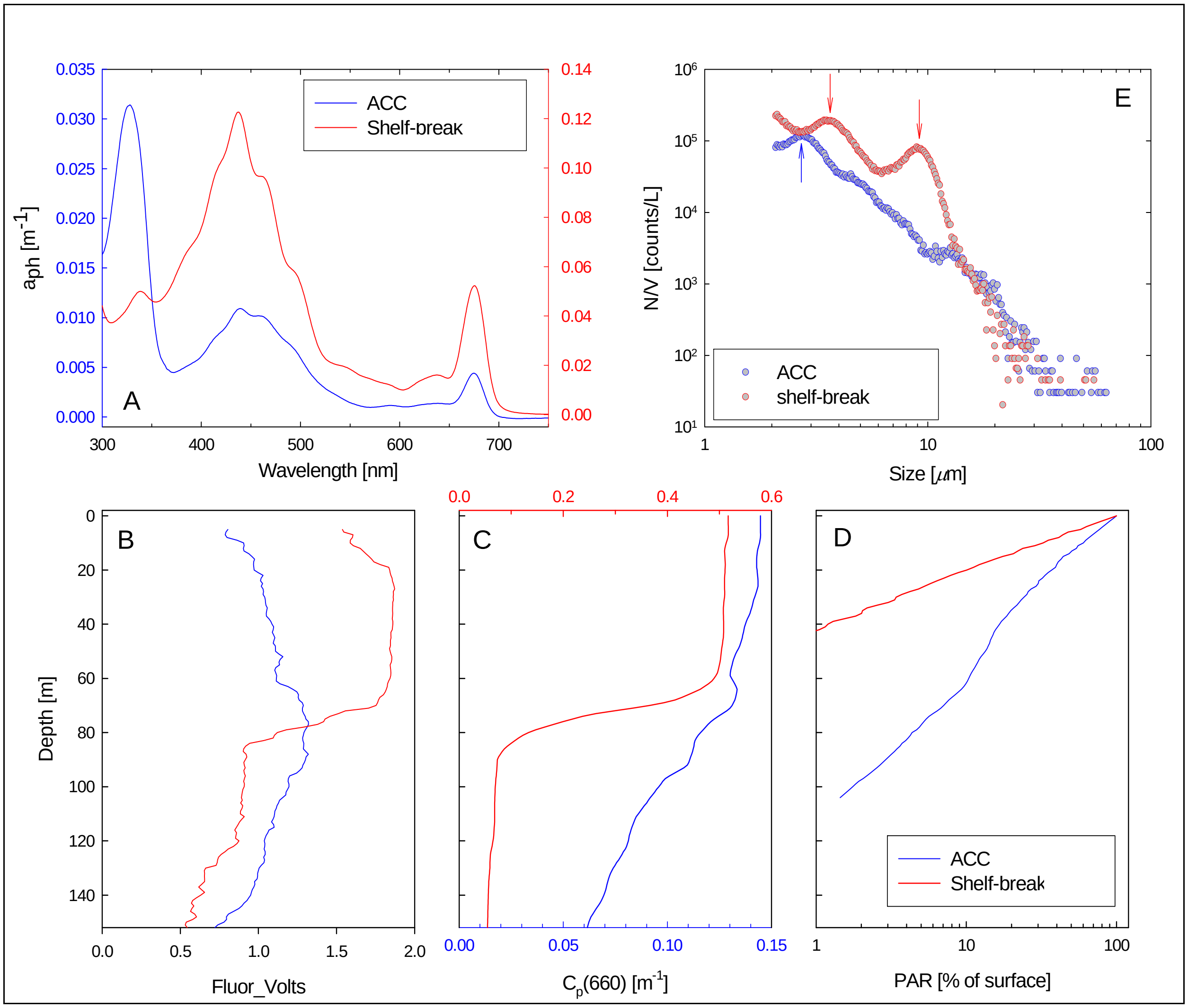

Fig.2.7. Comparison of bio-optical properties between Drake Passage waters (Station A09-04) and shelf-break waters (Station A08-06). (**A**) Phytoplankton absorption spectra of samples taken from 10mm depth - note changed of scales on the ordinate axis. (**B**) Profiles of CTD fluorometer voltage for top 150m. (**C**) Profiles of beam attenuation at red channel of 660nm. (**D**) Profiles of Photosynthetically Available Radiation (PAR), as percentage of PAR just below the surface. (**E**) Size distribution of particles at 10m.

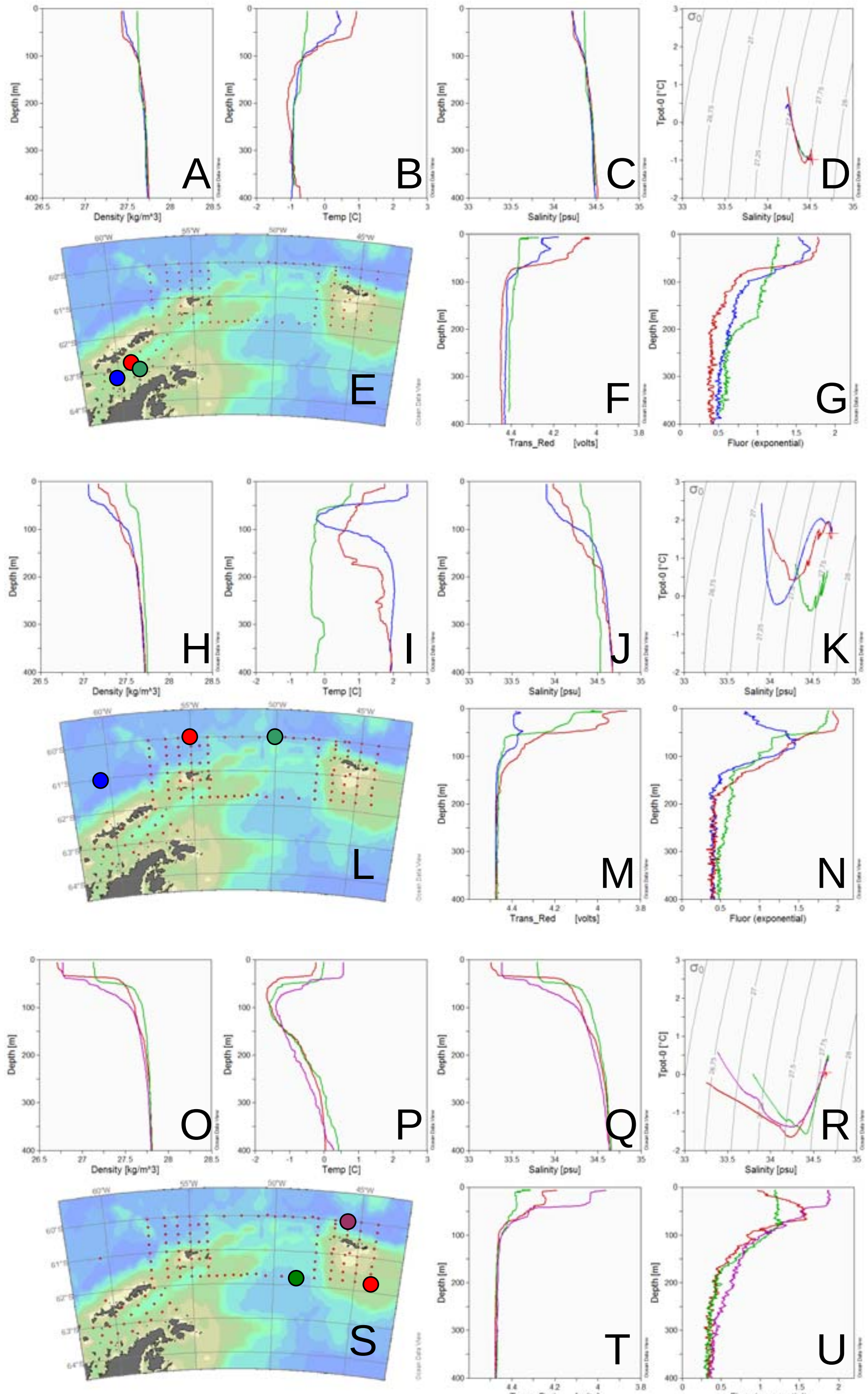

Fig.2.8. Hydrographic and phytoplankton characteristics for 3 contrasting stations in each of regional areas. Representing the South Area (A-G) with waters of the Bransfield Strait, stations D11-13, D14-14, and D12-12 represent 0.36, 0.84, and 1.21 mg Chl-a m^{-3}, respectively, as averaged over the UML. In waters of the Antarctic Circumpolar Current (H-N), stations C-1505, SO-004, and D04-01 represent 0.11, 0.91, and 1.62 mg Chl-a m^{-3}, respectively, as averaged over the UML. For the South Orkney area (O-U) stations SO-035, SO-015, and SO-008, represent 0.13, 0.40, and 1.70 mg Chl-a m^{-3}, respectively, as averaged over the UML. Profiles in depth (0-400 m) for density (A, H, O), temperature (B, I, P), salinity (C, J, Q), temperature in salinity space (T/S; D, K, R), and associated relationships with phytoplankton biomass represented by red absorbance (660 nm transmissometer; F, M, T) and Chl-a fluorescence (10^{Volts}; G, N, U). Station locations (E, L, S) with color of the symbol associated with line color.

3. Bioacoustic survey; submitted by Anthony M. Cossio and Christian Reiss

3.1 Objectives: The primary objectives of the bioacoustic survey were to map the meso-scale dispersion of Antarctic krill (*Euphausia superba*) in the vicinity of the South Shetland Islands and to determine their association with predator foraging patterns, water mass boundaries, spatial patterns of primary productivity, and bathymetry. In addition, efforts were made to map the distribution of myctophids and to determine their relationship with water mass boundaries and zooplankton distribution.

3.2 Methods and Accomplishments: Acoustic data were collected using a multi-frequency echo sounder (Simrad EK60), configured with down-looking 38, 70, 120, and 200 kilohertz (kHz) split-beam transducers, mounted in the hull of the ship. System calibrations were conducted before and after the survey using standard sphere techniques while the ship was at anchor in Ezcurra Inlet, King George Island. During the surveys, pulses were transmitted every 2 seconds at 1 kilowatt for 1 millisecond duration at 38 kHz, 70 kHz, 120 kHz, and 200 kHz. Geographic positions were logged simultaneously every 2 seconds. Ethernet communications were maintained between the EK60 and a Windows XP workstation. The workstation was used for primary system control, data logging, and data processing with Myriax's Echoview software.

Acoustic surveys of the water surrounding the South Shetland Islands were divided into four areas (See Figure 2 in Introduction): (1) a 43,865 km^2 area centered on Elephant Island (Elephant Island Area) was sampled with seven north-south transects; (2) a 38,524 km^2 area along the north side of the southwestern portion of the South Shetland archipelago (West Area) was sampled with six transects oriented northwest-southwest and one oriented north-south; (3) a 24,479 km^2 area in the western Bransfield Strait (South Area) was sampled with seven transects oriented northwest-southwest; (4) and an 18,151 km^2 area north of Joinville Island (Joinville Island Area). During the second leg of the cruise, the Elephant Island Area and the South Area were re-surveyed with only 6 transects in the Elephant Island Area. The West Area was not re-surveyed because of time limits. The area surrounding the South Orkney Islands was also sampled during the second leg and split into two different areas. The northern and southern sections of the South Orkney Islands were divided at 60.5° South. The northern section consisted of five north-south transects that covered an area of 10,841 km^2 and the southern section consisted of five north-south transects that covered an area of 21,190 km^2.

Data collected while at biological sampling stations were discarded. Only daytime data were used in analysis due to possible bias from diurnal vertical migration (Demer and Hewitt, 1995).

3.2.1 Krill Delineation: Krill are delineated from other scatters by use of a three frequency ΔS_v method (Hewitt et al., 2003; Reiss et al., 2008). The ΔS_v range is dynamic and is based on krill length ranges present in each survey area (CCAMLR, 2005). This differs from previous work when analyses were conducted using a constant range of ΔS_v ($4 \leq (S_{v,120} - S_{v,38}) \leq 16$ dB and $-4 \leq (S_{v,200} - S_{v,120}) \leq 2$ dB). Table 3.1 shows the ranges of krill lengths as well as the dynamic ΔS_v ranges used between 1996 and present.

3.2.2 Myctophid Delineation: A ΔMVBS window of -5 to 2dB was applied to a two-frequency (38 kHz and 120 kHz) method for the purpose of delineating myctophids. This range was chosen based on observed differences in myctophid backscattering values between 38 kHz and 120 kHz.

3.2.3 Abundance Estimation and Map Generation: Backscatter values were averaged over 5m by 100s bins. Time varied gain (TVG) noise was subtracted from the echogram and the ΔS_v range was applied. TVG values were based on levels required to erase the rainbow effect plus 2dB. The remaining volume backscatter classified as krill was integrated over depth (500m) and averaged over 1,852m (1 nautical mile) distance intervals.

Integrated krill nautical area scattering coefficient (NASC) (Maclennan and Fernandes, 2000) was converted to estimates of krill abundance (ρ) by dividing the sum of the weighted-mean masses per animal (W; g/krill) by the sum of the backscattering cross-sectional area of krill (σ) ($\sigma = 4\pi r 10^{TS/10}$ where r is the reference range of 1m; Hewitt and Demer, 1993). The length to weight relationship

$$W\text{ (g)} = 2.236 * 10^{-3} * TL^{3.314} \quad (1)$$

was based on net samples collected during the international krill biomass survey of the Scotia Sea conducted during January 2000 (Hewitt *et al.*, 2004). Krill abundance was estimated according to Hewitt and Demer (1993):

$$\rho\ (\text{g/m}^2) = \frac{\sum_{i=1}^{n} f_i W(l_i)}{\sum_{i=1}^{n} f_i \sigma(l_i)} NASC \quad (2)$$

where f_i = the relative frequency of krill of standard length l_i. Krill biomass was then estimated by multiplying ρ by the Area surveyed.

For each Area in each survey, mean biomass density attributed to krill and its variance were calculated by assuming that the mean abundance along a single transect was an independent estimate of the mean abundance in the area (Jolly and Hampton, 1990). We used the cluster estimator of Williamson (1982) to calculate the variance of NASC within each area and to expand the abundance estimate for the South Shetlands.

No myctophid biomass estimates were made because of the lack of target strength data and length frequency distributions. Instead, the NASC attributed to myctophids was integrated using SonarData Echoview software and then mapped across the South Shetland Islands using SURFER (Golden Software, Inc. Golden, CO).

3.3 Tentative Conclusions:

3.3.1 : Mean krill abundance for each transect line in each area is presented in Tables 3.2 and 3.3. Mean krill abundance was 17, 41, and 42 g/m² for the West, Elephant Island, and South Areas, respectively, during Leg 1. For Leg 2, abundance estimates were 33, 15, 129, and 61 g/m² for the Elephant Island, South Area and South Orkney Islands northern and southern sections, respectively (Table 3.4). Krill distributions were highest around Elephant Island and to the northwest of the South Orkney Islands (Figures 3.1 and 3.3).

The distribution of mean NASC of myctophids was mapped and was highest along the 2000m isobath (Figures 3.2 and 3.4). This is similar to previous years' patterns.

3.4 Protocol Changes:
There were no protocol changes or problems that arose during the acoustic survey.

3.5 Disposition of Data: All integrated acoustic data will be made available to other U.S. AMLR investigators in ASCII format files. The analyzed echo-integration data consume approximately 10 MB. The data are available from Anthony Cossio, Southwest Science Center, 8604 La Jolla Shores Dr, La Jolla, CA 92037; phone/fax – (858) 546-5609/546-5608; e-mail: Anthony.Cossio@noaa.gov.

3.5 References:

CCAMLR, 2005. Report of the first meeting of the subgroup on acoustic survey and analysis methods. SC-CAMLR-XXIV/BG/3.

Conti, S. G., and Demer, D. A. 2006. Improved parameterization of the SDWBA for estimating krill target strength. *ICES Journal of Marine Science* 63: 928-935.

Demer, D. A. and Conti, S. G. 2005. New target-strength model indicates more krill in the Southern Ocean. *ICES Journal of Marine Science* 62: 25-32.

Demer, D.A. and Hewitt, R.P. 1995. Bias in acoustic biomass estimates of Euphausia superba due to diel vertical migration. *Deep Sea Research I* 42: 455-475.

Greene, C. H., Wiebe, P. H., and McClatchie, S. 1991. Acoustic estimates of krill. *Nature* 349: 110.

Hewitt, R.P. and Demer, D.A. 1993. Dispersion and abundance of Antarctic krill in the vicinity of Elephant Island in the 1992 austral summer. *Marine Ecology Progress Series* 99:29-39.

Hewitt, R.P., Demer, D.A., and Emery J.H. 2003. An eight year cycle in krill biomass density inferred from acoustic surveys conducted in the vicinity of the South Shetland Islands during the austral summers of 1991/92 through 2001/02. *Aquatic Living Resources* 16(3): 205-213.

Hewitt, R. P, Watkins, J, Naganobu, M, Sushin, V, Brierley, A. S, Demer, D. A., Kasatkina, S., Takao, Y., Goss, C., Malyshko, A., Brandon, M. A., Kawaguchi, S., Siegel, V., Trathan, P. H., Emery, J., Everson, I., and Miller, D. 2004. Biomass of Antarctic krill in the Scotia Sea in January/February 2000 and its use in revising an estimate of precautionary yield. *Deep Sea Research II* 51: 1215-1236.

Jolly, G.M. and Hampton, I. 1990. A stratified random transect design for acoustic surveys of fish stocks. *Can. J. Fish. Aquat. Sci*. 47:1282-1291.

Maclennan, H. and Fernandes, P. Definitions, units and symbols in fisheries acoustics. Draft 03/04/00. Contr FAST Working Group Meeting, Haarlem, April 2000. 6p.

Reiss, C.S., Cossio, A.M., Loeb, V. and Demer, D.A. 2008. Variations in the biomass of Antarctic krill (*Euphausia superba*) around the South Shetland Islands, 1996-2006. *ICES Journal of Marine Science* 65:497-508.

Williamson, N. 1982. Cluster sampling estimation of the variance of abundance estimates derived from quantitative echo sounder surveys. *Can. J. Fish. Aquat. Sci*. 39:229-231.

Table 3.1. Range of total lengths (TL, mm) and acoustic ΔS_v ranges applied to assess biomass of Antarctic krill in the Elephant Island, South and West Areas of the South Shetland Islands region between 1998 and 2008, using the simplified SDWBA model (see Conti and Demer, 2005; and CCAMLR, 2005).

Cruise	Elephant Island Krill length	120-38 kHz	200-120 kHz	West Krill length	120-38 kHz	200-120 kHz	South Krill length	120-38 kHz	200-120 kHz
1996A	18-59	2.5 to 14.7	-0.5 to 2.1	x	x	x	x	x	x
1996D	20-57	2.5 to 14.7	-0.5 to 2.1	x	x	x	x	x	x
1997A	19-58	2.5 to 14.7	-0.5 to 2.1	17-58	2.5 to 17.7	-0.5 to 6.8	15-52	2.5 to 17.7	-0.5 to 6.8
1998A	17-53	2.5 to 17.7	-0.5 to 6.8	15-52	2.5 to 17.7	-0.5 to 6.8	16-44	4.6 to 17.7	-0.5 to 6.8
1998D	21-52	2.5 to 14.7	-0.5 to 2.1	19-53	2.5 to 14.7	-0.5 to 2.1	19-48	4.6 to 14.7	-0.5 to 2.1
1999A	32-54	2.5 to 11.1	-0.5 to 0.4	30-54	2.5 to 11.1	-0.5 to 0.4	26-52	2.5 to 14.7	-0.5 to 2.1
1999D	35-56	2.5 to 11.1	-0.5 to 0.4	36-51	4.6 to 11.1	-0.5 to 0.4	x	x	x
2000D	39-58	2.5 to 7.7	-0.5 to -0.3	39-59	2.5 to 7.7	-0.5 to -0.3	40-55	2.5 to 7.7	-0.5 to -0.3
2001A	18-57	2.5 to 14.7	-0.5 to 2.1	40-60	2.5 to 7.7	-0.5 to -0.3	22-55	2.5 to 14.7	-0.5 to 2.1
2001D	26-60	2.5 to 14.7	-0.5 to 2.1	26-60	2.5 to 14.7	-0.5 to 2.1	28-57	2.5 to 14.7	-0.5 to 2.1
2002A	17-59	2.5 to 17.7	-0.5 to 6.8	18-60	2.5 to 17.7	-0.5 to 6.8	20-45	4.6 to 14.7	-0.5 to 2.1
2002D	21-59	2.5 to 14.7	-0.5 to 2.1	20-56	2.5 to 14.7	-0.5 to 2.1	20-49	4.6 to 14.7	-0.5 to 2.1
2003A	13-53	2.5 to 17.7	-0.5 to 6.8	13-54	2.5 to 17.7	-0.5 to 6.8	13-45	4.6 to 17.7	-0.5 to 6.8
2003D	15-53	2.5 to 17.7	-0.5 to 6.8	19-54	2.5 to 14.7	-0.5 to 2.1	16-49	4.6 to 17.7	-0.5 to 6.8
2004A	21-55	2.5 to 14.7	-0.5 to 2.1	24-57	2.5 to 14.7	-0.5 to 2.1	20-57	2.5 to 14.7	-0.5 to 2.1
2004D	29-58	2.5 to 11.1	-0.5 to 0.4	22-55	2.5 to 14.7	-0.5 to 2.1	18-56	2.5 to 17.7	-0.5 to 6.8
2005A	20-59	2.5 to 14.7	-0.5 to 2.1	21-57	2.5 to 14.7	-0.5 to 2.1	20-57	2.5 to 14.7	-0.5 to 2.1
2005D	28-57	2.5 to 14.7	-0.5 to 2.1	39-55	2.5 to 7.7	-0.5 to -0.3	19-53	2.5 to 14.7	-0.5 to 2.1
2006A	25-61	2.5 to 14.7	-0.5 to 2.1	41-60	2.5 to 7.7	-0.5 to -0.3	26-59	2.5 to 14.7	-0.5 to 2.1
2007A	16-60	2.5 to 17.7	-0.5 to 6.8	19-58	2.5 to 14.7	-0.5 to 2.1	19-55	2.5 to 14.7	-0.5 to 2.1
2008A	19-57	2.5 to 14.7	-0.5 to 2.1	19-57	2.5 to 14.7	-0.5 to 2.1	16-56	2.5 to 17.7	-0.5 to 6.8
2008D	19-58	2.5 to 14.7	-0.5 to 2.1	x	x	x	21-51	4.6 to 14.7	-0.5 to 2.1

Table 3.2. Daytime krill abundance estimates by Area and transect for Leg I and Leg II of the survey. n = 1 interval = 1 nautical mile.

Area	Transect	n	Krill abundance (g/m^2)
West Area			
	Transect 1	35	38.9
	Transect 2	50	35.3
	Transect 3	14	49.5
	Transect 4	70	19.6
	Transect 5	39	4
	Transect 6	46	0.1
	Transect 7	112	8.7
Elephant Island Area			
	Transect 1	97	70.4
	Transect 2	95	53.7
	Transect 3	104	84.9
	Transect 4	115	4.2
	Transect 5	106	11.3
	Transect 6	94	6.3
	Transect 7	74	70.4
South Area			
	Transect 1	31	5.9
	Transect 2	44	107.3
	Transect 3	42	0.04
	Transect 4	46	34.1
	Transect 5	42	90.2
	Transect 6	0	n/a
	Transect 7	40	0.5
Elephant Island Area			
	Transect 1	69	19.2
	Transect 2	n/a	n/a
	Transect 3	63	0.04
	Transect 4	68	17.3
	Transect 5	89	84.1
	Transect 6	101	0.4
	Transect 7	85	63.7
South Area			
	Transect 1	16	0.002
	Transect 2	41	35.3
	Transect 3	0	n/a
	Transect 4	41	0.2
	Transect 5	11	4
	Transect 6	13	67.5
	Transect 7	39	0.8

Table 3.3. Range of TL (mm) and acoustic ΔS_v ranges applied to assess biomass of Antarctic krill in the South Orkney Islands Area. Daytime krill abundance estimates by area and transect for the South Orkney Islands Area.
n = 1 interval = 1 nautical mile.

Area	**Krill Length**	**120-38 kHz**	**200-120 kHz**
South Orkney Islands - North	22-49	4.6 to 14.7	-0.5 to 2.1
South Orkneys Islands - South	22-49	4.6 to 14.7	-0.5 to 2.1

Area	**Transect**	**n**	**Krill abundance (g/m^2)**
South Orkney Islands - North			
	Transect 1	31	48.8
	Transect 2	31	325.6
	Transect 3	29	104.7
	Transect 4	31	63.2
	Transect 5	28	98.5
South Orkneys Islands - South			
	Transect 1	54	117.5
	Transect 2	16	116.2
	Transect 3	66	50.6
	Transect 4	16	6.6
	Transect 5	66	25

Table 3.4. Mean krill biomass for surveys conducted from 1996 to 2008. Coefficients of variation (CV) are calculated by the methods described in Jolly and Hampton, 1990, and describe measurement imprecision due to the survey design. Only one survey was conducted in 1997; 1999 South Area D values are not available due to lack of data. See Figure 2 in the Introduction Section for description of each survey.

Survey	**Area**	**Area (km²)**	**Mean Density (g/m²)**	**Biomass (10³ tons)**	**CV %**
1996 A (late January)	Elephant Island	41,673	55.27	2,666	28.5
D (early March)	Elephant Island	41,673	35.66	1,720	29.3
1997 A (late January)	Elephant Island	41,673	24.43	1,178	23.8
	West	34,149	36.8	1,257	31.3
	South	8,102	41.38	236	51.2
1998 A (late January)	Elephant Island	41,673	31.76	1,324	25.5
	West	34,149	56.4	1,927	25.9
	South	8,102	41.1	333	23
D (late February)	Elephant Island	41,673	10.83	451	29.4
	West	34,149	18.3	625	27.2
	South	8,102	24.75	200	38.5
1999 A (late January)	Elephant Island	41,673	7.19	300	47.3
	West	34,149	8.89	304	33.8
	South	8,102	23	186	18.3
D (late February)	Elephant Island	41,673	10.7	446	68.1
	West	34,149	6.88	235	41.8
2000 D (late February)	West	34,149	4.51	154	32.2
	Elephant Island	41,673	3.67	153	36.3
	South	8,102	2.51	20	0.5
2001 A (late January)	West	34,149	0.13	4	51.1
	Elephant Island	41,673	13.44	560	21.6
	South	8,102	9.83	80	29.9
D (late February)	West	34,149	15.12	516	60.5
	Elephant Island	41,673	14.44	602	11.4
	South	8,102	5.61	45	51.5
2002 A (late January)	West	38,524	21..02	810	44.6
	Elephant Island	43,865	51.92	2,277	14.9
	South	24,479	4.28	105	48.2
D (late February)	West	38,524	0.41	16	46.4
	Elephant Island	43,865	4.73	208	26.5
	South	24,479	2.97	726	79.9
2003 A (late January)	West	38,524	54.28	2,091	21.8
	Elephant Island	43,865	57.79	2,535	13.4
	South	24,479	57.19	1,400	29.9
D (late February)	West	38,524	41.82	1,611	29.5
	Elephant Island	43,865	37.86	1,661	21.2
	South	24,479	80.02	1,959	20.4
2004 A (late January)	West	38,524	34.37	1,324	8.9
	Elephant Island	43,865	21.41	939	17.4
	South	24,479	7.22	177	48

D (late February)	West	38,524	18.87	727	44
	Elephant Island	43,865	3.51	154	42.1
	South		46.59	1,141	51.4
2005 A (late January)	West	38,524	17.11	659	26.6
	Elephant Island	43,865	11.93	523	55
	South	24,479	3.93	96	55.7
D (Late February)	West	38,524	0.37	17	85.2
	Elephant Island	43,865	0.75	33	37.1
	South	24,479	1.97	48	21.4
2006 (Late January)	West	38,524	0.81	3	45.9
	Elephant Island	43,865	3.46	152	38.9
	South	24,479	1.95	48	49.3
2007 (Late January)	West	38,524	29.23	1,126	19.7
	Elephant Island	43,865	148.87	6,530	33.7
	South	24,479	12.89	315	40.9
2008 A (Late January)	West	38,524	17.31	667	31.6
	Elephant Island	43,865	41.24	1,809	32.8
	South	24,479	41.96	1,027	47.2
SO (Late February)	South Orkneys North	10,841	129.09	1,399	40.3
	South Orkneys South	21,190	61.0	1,2934	34.6
D (Early March)	Elephant Island	43,865	32.53	1,427	47.4
	South	24,479	14.96	366	62.8

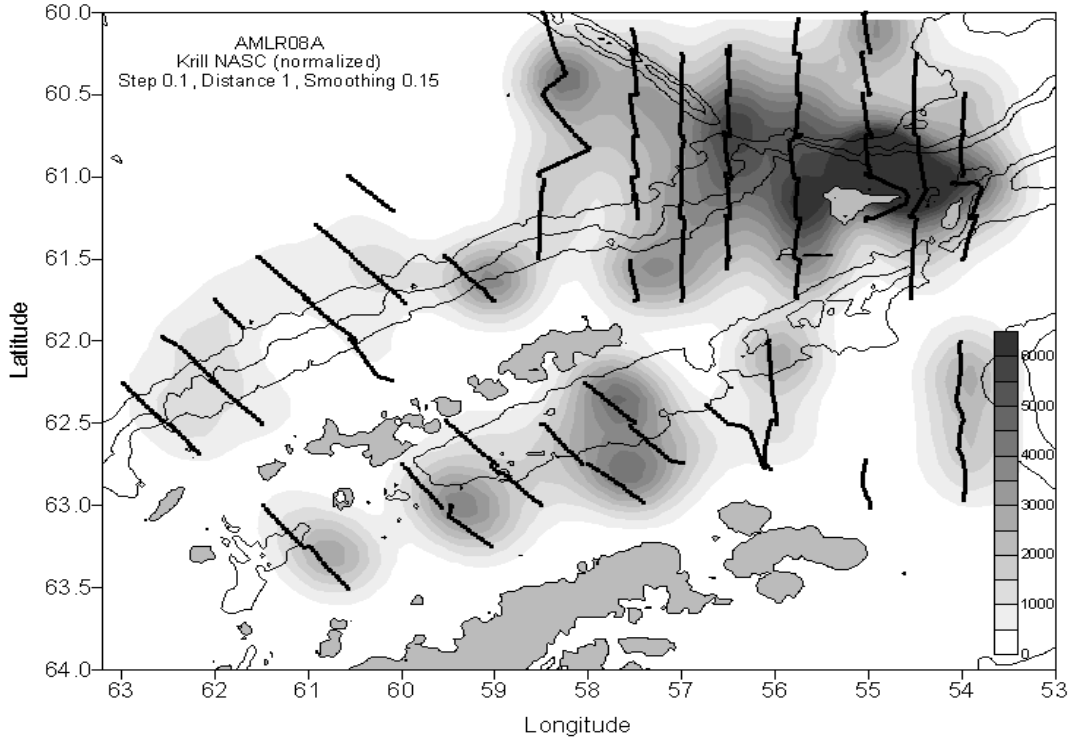

Figure 3.1. Normalized krill NASC values for Survey A (South Shetland Islands) at 120 kHz using day data. (Latitude is south and longitude is west).

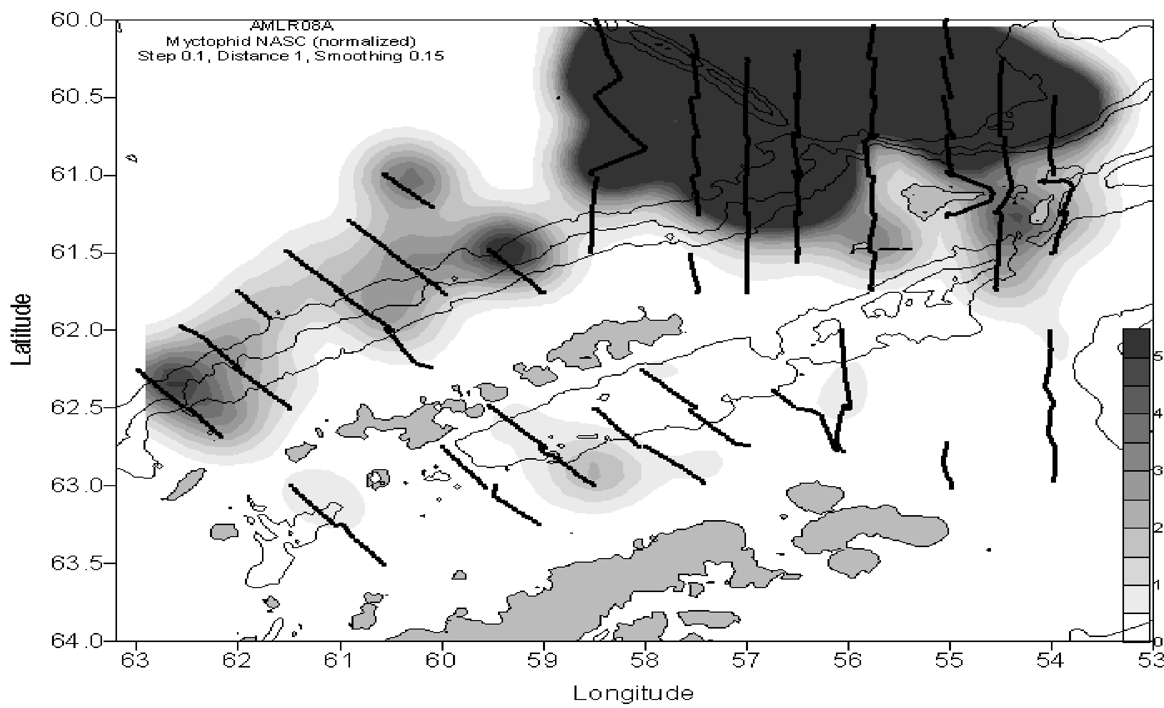

Figure 3.2. Normalized myctophid NASC values for Survey A (South Shetland Islands) at 120 kHz using day data. (Latitude is south and longitude is west).

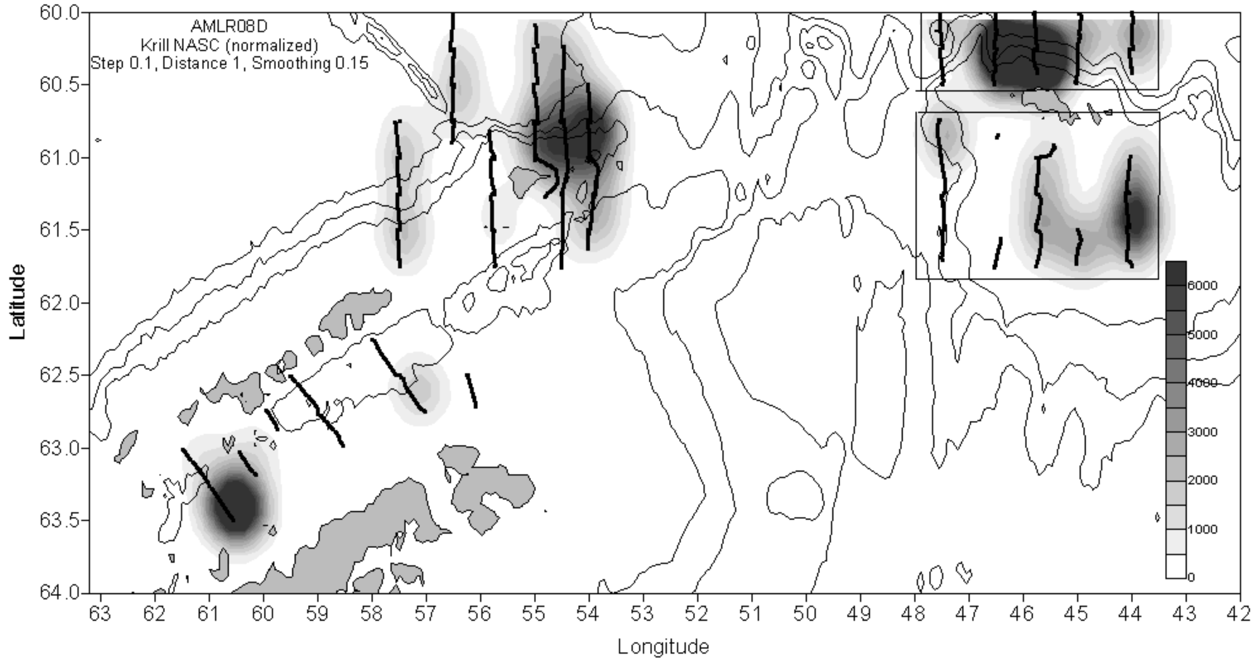

Figure 3.3. Normalized krill NASC values for Survey D (South Shetland and South Orkney Islands) at 120 kHz using day data. (Latitude is south and longitude is west).

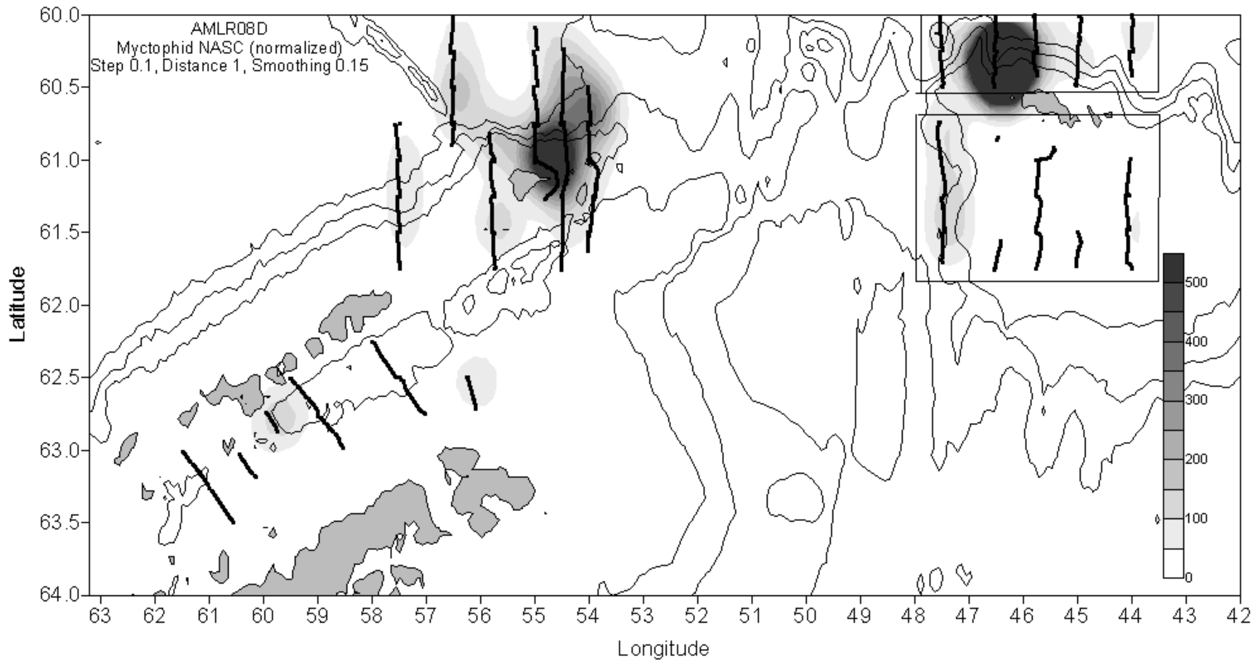

Figure 3.4. Normalized myctophid NASC values for Survey D (South Shetland and South Orkney Islands) at 120 kHz using day data. (Latitude is south and longitude is west).

AMLR 2008: Net sampling: Krill and zooplankton; submitted by Valerie Loeb, Cassandra Brooks, Kimberly Dietrich, Ryan Driscoll, Darci Lombard, Lia Protopapadakis, Nicolas Sanchez and Kyla Zaret.

4.1 Objectives:

Here we provide information on the distribution, abundance and demographic structure of Antarctic krill (*Euphausia superba*), and on the abundance and distribution of salps and other zooplankton taxa, in the vicinity of the South Shetland Islands (Elephant, King George, Livingston and Joinville Islands), the South Orkney Islands (north and south shelf areas) and the waters between these two regions. Essential krill demographic information includes: length, sex ratio, maturity stage composition and reproductive condition. Information useful for determining the relationships between krill and zooplankton distribution patterns and ambient environmental conditions was derived from net samples taken at established CTD/phytoplankton stations. Biomass dominant copepod species and the salps *Salpa thompsoni* and *Ihlea racovitzai* receive special attention because their interannual abundance variations reveal underlying hydrographic processes influencing the Antarctic Peninsula ecosystem. Results from the two month-long cruises (Surveys A and D) are compared to those from previous AMLR surveys to assess between-season and between-year differences in krill demography and zooplankton composition and abundance over the 1992-2008 period. Data from 2000-2007 have been revised to accommodate a systematic flow volume conversion factor that artificially increased krill and zooplankton abundance estimates by ca. 33% in field season reports from those years. Additional historical data from the Elephant Island Area are used to examine copepod species abundance and abundance relations between 1981 and present. Data from the South Orkney Islands and Elephant Island Area collected during Survey D are compared to assess spatial variation in krill abundance and demography and zooplankton composition relative to hydrographic conditions east and west of the Shackleton Fracture Zone. Of special interest is the importance of the South Orkney Island region in supporting an actively reproductive krill population.

4.2 Methods:

4.2.1 Net Samples: Krill and zooplankton were obtained from a 1.8 m Isaacs-Kidd Midwater Trawl (IKMT) fitted with a 505 μm mesh plankton net. Flow volumes were measured using a calibrated General Oceanics flow meter mounted on the frame in front of the net. All tows were fished obliquely from a depth of 170m or to ca. 10m above bottom in shallower waters. Real-time tow depths were derived from a depth recorder mounted on the trawl bridle. Tow speeds were ca. two kts with flow volumes averaging 4200 (+/- 730) m^3 based on a calibration factor of 0.0752 calculated from the net fishing dimensions.

4.2.1 Survey A: Samples collected at survey stations during Survey A are derived from four distinct areas in the South Shetland Island Area (**AMLR Overview Report, this volume; Figure 4.1A**). "Elephant Island Area" stations represent the historically sampled area used for long-term analyses of the Antarctic Peninsula marine ecosystem. "West Area" stations, north of King George and Livingston Islands, form a database with which to examine the abundance and length composition of krill to predator populations at Cape Shirreff and to the krill fishery that operates in this area during summer months. Additionally, the composition and abundance of zooplankton assemblages in the West and Elephant Island Areas reflect prevailing hydrographic influences, specifically the eastward flowing Antarctic Circumpolar Current (ACC) and its zooplankton-rich Upper Circumpolar Deep Water (UCDW) environment and comparatively depauperate westward flowing coastal currents. Within Bransfield Strait the "South Area" stations are used to monitor krill supplies available to predator populations monitored at the Copacabana field camp on King George Island while "Joinville Island Area" stations, to the east, are sampled to increase the likelihood of encountering infrequent but dense aggregations of juvenile krill that during some years are primarily distributed within southern Bransfield Strait (Siegel et al., 2002).

4.2.2 Survey D: Survey D included a first-time AMLR krill sampling effort in the vicinity of the South Orkney Islands (Fig. 4.1B). The South Orkney Island samples provide the basis for comparison with the regularly surveyed South Shetland Island Region, specifically with respect to krill abundance and demography. This is of specific interest because commercial krill trawlers regularly fish around the South Orkney Islands. The area is subdivided into "North Shelf" and "South Shelf" components to examine regional differences in krill abundance and demography and zooplankton assemblages. Survey efforts conducted during the eastward and westward transits between the Elephant Island Area and South Orkney Islands provide a basis for assessing advective transport of postlarval and larval krill from upstream source areas. Furthermore, these samples reflect the importance of hydrographic features in structuring the marine ecosystem leeward of the Shackleton Fracture Zone where the ACC is deflected offshore by bottom topography.

The Elephant Island and South Areas were also sampled during Survey D and provide information on seasonal changes in krill distribution and demography, as well as zooplankton composition and abundance for the long-term database. Of specific importance are changes in krill reproductive effort and larval krill abundance over the summer season that are directly related to year class success and recruitment the following year. Additionally, data on krill demographics and abundance in the Elephant Island Area are essential for assessing the importance of this area as a source of animals advected downstream to the South Orkney Island Area.

4.2.3 Shipboard Analyses: All samples were processed on board. Krill demographic analyses were conducted using fresh or freshly frozen specimens. Other zooplankton analyses were conducted using fresh material within two hours of sample collection. Abundance estimates of krill, salps, copepods and other taxa are expressed as numbers per 1000 m^3 water filtered. For diel considerations twilight samples are defined as those collected one hour before to one hour after local sunrise and sunset.

(A) Krill: Krill were removed and counted prior to other sample processing. All krill from samples of <100 individuals were analyzed. For larger samples, generally 100 individuals were measured, sexed, and staged. Krill total length (mm) was measured and reproductive stage was determined based on the classification scheme of Makarov and Denys (1981). Length-at-age estimates are based on Siegel (1987) and Siegel and Loeb (1994).

(B) Salps: Salps were removed from samples of two liters or less and enumerated. For larger catches the numbers of salps in one to two liter subsamples were used to estimate abundance. For samples with $\leq$100 individuals, the two life stages (aggregate/sexual and solitary/asexual) were enumerated and internal body length (Foxton, 1966) was measured to the nearest millimeter. Representative subsamples of $\geq$100 individuals were analyzed in the same manner for larger catches.

(C) Fish: All adult myctophids were removed, identified, measured to the nearest millimeter, and frozen.

(D) Zooplankton: After krill, salps and adult fish were removed from the IKMT samples, the remaining zooplankton fraction was analyzed. All of the larger organisms (e.g., other postlarval euphausiids, amphipods, pteropods, polychaetes) were sorted, identified to species if possible, and enumerated. Following this the samples were aliquoted and smaller zooplankton (e.g., copepods, chaetognaths, euphausiid larvae) in three or four subsamples were enumerated and identified to species if possible using dissecting microscopes. After analysis the zooplankton samples (without adult fish, postlarval krill, most salps) were preserved in 10% buffered formalin for long-term storage. Specimens of pteropods belonging to genera with calcareous shells, *Limacina* and *Clio*, were preserved separately in buffered 95% ethanol for use in ocean acidification studies.

The long-term AMLR zooplankton data set reflects the evolution of shipboard sample processing and identification techniques. Taxonomic diversity increases evident over the past decade result in part from the identification of smaller taxa such as copepod species and euphausiid larvae. Additionally, survey grid expansions into higher latitudes and, this year, eastward to the South Orkney Island region, incorporate zooplankton taxa not encountered during earlier surveys. Most notable are areas influenced by Weddell Sea shelf water (eastern Elephant Island and Joinville Island Areas) and by outflow from Gerlache Strait (southwestern Bransfield Strait). Use of a more protective cod-end starting in 2002 also increased the numbers of previously unidentifiable delicate taxa such as jellies and pteropods.

4.2.4 Statistical Analyses: Data from the entire survey area and four subareas are analyzed for within-cruise and between-year comparisons. Krill, salp and zooplankton species abundances are also related to hydrography using water zones as described in the Physical Oceanography Section of this report (Chapter 1). These Water Zone numbers I to V represent a variety of mixtures between Antarctic Circumpolar Current (ACC) (I), ACC-derived (II and III), Bransfield Strait (IV) and high latitude Weddell Sea shelf water (V). Analyses include a variety of parametric and nonparametric techniques including Index of Dispersion (ID), Analysis of Variance (ANOVA), Kendall's Tau (*T*) correlations, Cluster Analysis, Percent Similarity Indices (PSIs) and Kolmogorov-Smirnov cumulative percent curve comparisons (D_{MAX}). Cluster analyses use Euclidean distance and Ward's linkage method; clusters are distinguished by a distance of 0.30 to 0.70. Clusters based on size characteristics utilize proportional length-frequency distributions in each sample with at least 17 krill or 80 salps. Zooplankton clusters are based on log-transformed sample abundance data (N+1) for taxa present in at least 20% of samples. Statistical analyses were performed using *Statistica* software (StatSoft).

4.2.5 Long Term Data Sets: Because of the extensive temporal coverage in various instances (e.g., zooplankton species abundance) it is no longer practical to tabulate all of the AMLR survey data collected prior to 1998. When lacking here, information from 1990-1997 is available in previous AMLR Field Season Reports in print versions and on the AMLR Website: (http://swfsc.noaa.gov/textblock.aspx?division=AERD&id=5765).

4.3 Accomplishments:

Due to harsh weather conditions and related loss of, or damage to, net sampling gear during the first 10 days of Survey A, our sampling effort was reduced to 22 of the 25 standard West Area stations and 34 of 48 Elephant Island Area stations. However, reduced ice cover in Bransfield Strait allowed us to sample all stations there, increasing the total number of stations to 10 in the Joinville Island Area and 20 in the South Area. As a consequence, the resulting total number of samples from the Survey A, 86, and Elephant Island Area were comparable to other years when similar conditions were encountered (e.g., 1999 and 2003).

4.4 Results and Preliminary Conclusions:

4.4.1 Survey A:

4.4.1.1 Krill:

<u>Postlarval Frequency, Distribution and Abundance (Table 4.1A; Figure 4.1A)</u>
Krill were broadly distributed across the entire survey area and collected by 79 of the 86 (92%) net samples. Krill sample data, as well as mean, median and STD calculations, are found in Table 4.1. The largest catch of 8000 individuals (3560 per 1000 m^3) was located east of King George Island, adjacent to the eastern Bransfield Strait basin. Another relatively large catch also in the Elephant Island Area (2753 individuals, 1115 per 1000 m^3) occurred over the northwest shelf break while two others in the Joinville Island Area (2254-2767 krill, 820-1021 per 1000 m^3) were on the easternmost line of stations. Because the largest krill sample overwhelmingly dominated the Elephant Island Area data set it is excluded from demographic compilations and considerations.

The highest catch frequency (97%), largest median abundance (22 per 1000m^3) and relatively high mean abundance (186 per 1000m^3) were in the Elephant Island Area, reflecting a fairly uniform distribution there. Greatest mean abundance (258 per 1000m^3) was in the Joinville Island Area but, due to a highly patchy distribution, the median value was low (2 per 1000m^3) and similar to that observed in the South. Although krill were frequent in West and South Area samples (86% and 95%, respectively) the catch sizes were comparatively modest, leading to low mean values (49 and 40 per 1000m^3).

Length and Maturity Stage Composition (Table 4.2A; Figures 4.2A, 4.3A)
Krill lengths ranged from 14 to 57mm. The overall length-frequency distribution was bimodal with a large mode at 27mm and secondary mode at 42mm. The median length was 29mm and 90% of the total catch was represented by individuals $\leq$ 45mm, Data collected during the 2007/08 field season indicated the overwhelming dominance of one- and two-year old krill (i.e., the 2005/06 and 2006/07 year classes). The paucity of larger, older krill, including representatives of the successful 2004/05 year class, suggests that these individuals may have been further offshore and therefore under-sampled during the survey.

The 27mm length mode predominated in all four survey areas reflecting (1) strong recruitment success of the 2006/07 year class and (2) expansive northward distribution of smaller, younger krill stages during the survey effort. Despite this, spatial distribution differences of the length/maturity stages were evident among the four areas. Cumulative percent curve comparisons show that length-frequency distributions in the Joinville Island Area were substantially different from the other Areas (D_{MAX}= 32-36), while those in the Elephant Island and South Areas were the most similar (D_{MAX}=8). .The median length in the Joinville Island Area was 28mm and the vast majority (90%) of krill there were <40 mm one-year-old individuals, predominantly juveniles (69%) and immature males (22%) and females (5%). In the West Area, while the median length was 30mm, 25% of krill were $\geq$ 45mm, with lengths centered around 50mm, obviously including greater proportions of older krill than in the other areas. Here juveniles comprised 55%, immature stages 11% and mature individuals 34%. Males and females were equally represented. The mature krill were mostly female 3a-b (21%) and male 3b (11%); only 1% of the mature females were in advanced stages (3c-e). The adult maturity stage composition suggests initiation of the seasonal mating effort here during mid- to late-January. The Elephant Island and South Area krill had secondary length modes of 42mm, with 90% of individuals $\leq$ 45mm. While juveniles made up ca. 50% in both areas greater proportions of immature stages were in the South than in the Elephant Island Area (30% vs.16%). This difference was due to greater representation by immature males in the South Area: here males were 3X more abundant than females and two-year-old Stage 2c males comprised 12% vs. 4% of the total in the Elephant Island Area. In contrast, greater proportions of mature female stages were in the Elephant Island Area (23% vs. 10% in the South). Although relatively less abundant, the increased incidence of advanced (3c-e) stages among mature females in the South (31% vs. 24%) may result from the advancing season over the sampling period (to early February) and/or an earlier seasonal reproductive effort in Bransfield Strait.

Distribution Patterns (Figures 4.4A, 4.5A)
Cluster analysis applied to krill length-frequency distributions in 51 samples yielded three size clusters with somewhat coherent distribution patterns. Cluster 1, comprised 24 stations and was characterized by a dominant 27mm length mode and a 29mm median length. This Cluster was dominated by juvenile (61%) and immature (15%) stages. Of the 24% contributed by mature stages, females were almost 2X more abundant than males and over 25% of these were in advanced stages. This group was broadly distributed across the survey region and present in all water types. Its distribution pattern conformed to the major flow patterns depicted by dynamic height plots: from west of the South Shetlands; northward between King George and Elephant Islands; northeast between Elephant and Clarence Islands; and eastward through central Bransfield Strait (Chapter 1). Cluster 3 comprised just eight offshore stations, six in the West Area and two east of the Shackleton Fracture Zone, most of these stations were characterized by Type 1 (ACC) water. Krill associated with this cluster were larger, around 45-47mm and with a median length of 45mm. Juveniles and immature stages together represented only 13% of the

total of this cluster. Mature males constituted 37% and mature females 50%; a third of the females were in advanced reproductive stages (e.g., undergoing gonadal development, gravid or spent). Cluster 2, comprised the remaining 19 stations, and resembled Cluster 3 but also contained 35-44mm (i.e., two-year-old) krill. Immature males comprised 23%, mature males 26% and mature females 35% of the total. Most of the mature females were in mating stages (3a-b). The scattered distribution of these krill appeared to be associated with hydrographic features such as frontal zones and eddies in Bransfield Strait, north of the South Shetland Islands, around Elephant and Clarence Islands and offshore in the lee of the Shackleton Fracture Zone (Chapter 1).

<u>Larval Krill Distribution, Abundance and Stage Composition (Tables 4.3; 4.4A, 4.5A; Figure 4.6A)</u>
Larval krill were present in 58 samples (67%) with overall mean and median abundance values of 33 and 6.2 per 1000 m^3. Catch frequency and abundance increased as the survey progressed from the West (36%, 2.2 and 0 per 1000 m^3 mean and median), to Elephant Island (71%, 30 and 6.3 per 1000 m^3), Joinville Island (90%, 100 and 34 per 1000 m^3) and South Areas (85%, 38 and 17 per 1000 m^3) presumably resulting from the appearance in surface waters of larvae spawned during late December and early January). Larval development also advanced over the survey period from 80% and ca. 100% Calyptopis stage 1 (C1) in the West and Elephant Island Areas, to 66% C1 and 33% C2 in the South Area and 38% C1, 52% C2, 8% C3 in the Joinville Island Area. The larger overall abundance and proportions of advanced larval stages in the Joinville Island Area suggest the retention and concentration of larvae advected here from the South and Elephant Island Areas over the preceding month.

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4.4.1.2 Salps:

<u>*Salpa thompsoni* Frequency, Distribution and Abundance (Tables 4.4A, 4.5A; Figure 4.7A)</u>
Salpa thompsoni were collected in just over half of the samples (52%) with relatively low mean and median abundance (5 and 0.2 per 1000 m^3). Their distribution was predominantly in the West and Elephant Island Areas in shelf and offshore regions influenced by the ACC. They were absent from the Joinville Island Area and generally small concentrations were present in five of the 20 South Area samples providing low mean and median abundance values of 2 and 0 per 1000 m^3. While salps were most frequent in Elephant Island samples (76% vs. 68%) they were generally at smaller concentrations than in the West Area (5.2 and 2.6 per 1000 m^3 mean and median vs.10 and 6.0 per 1000 m^3).

<u>Size and Maturity Stage Composition (Figure 4.8)</u>
The sexually reproductive aggregate (chain) form composed 88% of the total salp catch. Individual lengths ranged from 4-58 mm with a 33 mm median and 27, 29 and 45 mm modes. Based on an estimated growth rate of 0.4mm per day, the onset of chain production was likely in early September. Seventy-five percent of the aggregates were reproductive sizes $\geq$25mm. Lengths of the asexually reproductive solitary form ranged from 4-130mm, with a median of 40mm and primary modes at 8, 35, 42, 47 and 55mm. The older individuals (e.g., 47 and 55 mm) are approaching maturity and most likely are overwintering individuals migrating to surface waters prior to late-summer budding. Small individuals represented by the 8 mm mode were recently released by the aggregates and will be part of the next overwintering population.

While aggregate and solitary length-frequency distributions did not differ among the three regions the proportion of solitaries in the Elephant Island Area was substantially higher than in the West and South Areas (21% vs. 4-5%). This resulted from elevated concentrations of solitaries offshore in the lee of the Shackleton Fracture Zone. Due to the relatively small sample sizes cluster analysis did not provide any insight into distribution patterns of the aggregate stage.

<u>*Ihlea racovitzai* (Tables 4.4A, 4.5A; Figure 4.7A)</u>

Small numbers of this high latitude salp species occurred in 11 samples, 8 of which were in Bransfield Strait, mostly the northern portion. The remaining three were over northern island shelf regions. Mean abundance in the West, South and Elephant Island Areas ranged from 0.2-0.5 per 1000 m^3.

4.4.1.3 Zooplankton and Micronekton Assemblage:

Overall Composition, Abundance and Distribution Patterns (Tables 4.4A, 4.5A; Figures 4.9A, 4.10A, 4.11A, 4.12A, 4.13A)
Copepods, postlarval *Thysanoessa macrura*, postlarval and larval krill numerically dominated the zooplankton during Survey A, together comprising 92% of total mean abundance. Sampling frequency, mean and median abundance values can be found in Table 4.4A and 4.5A. Copepods were represented in all 86 samples and *T. macrura* in 84 (98%). "Other" small unidentified copepod species and *Calanoides acutus* were the most frequently occurring taxa (both in 99% of samples) and had the greatest median abundance (187 and 75 per 1000 m^3) reflecting their widespread distributions. Coastal species *Metridia gerlachei*, present in 77% of samples, had the greatest mean abundance (261 per 1000 m^3), due to patchy dense concentrations, particularly in northern Bransfield Strait. Postlarval *T. macrurua* had fairly similar overall mean and median abundance values (234 and 140 per 1000 m^3) also due to their widespread distribution. Larval *T. macrura*, however, were comparatively rare, present in only 38% of samples with mean and median abundance of 6.2 and 0 per 1000 m^3. Postlarval *T. macrura* concentrations were primarily across northern Bransfield Strait, over and offshore of the island shelves while the larvae were most abundant in southern Bransfield Strait. Other frequent and relatively abundant taxa included chaetognaths, the amphipod *Primno macropa* and radiolaria which followed postlarval and larval krill in mean abundance.

The relatively uniform distribution patterns of the dominant taxa are reflected in PSI values from comparison of their proportional abundance within the four sub areas, generally 71-80. The most similar zooplankton assemblages were shared by the Elephant Island and South Areas (PSI= 90). Copepods were relatively more abundant in these two areas, comprising ca. 66% vs. 53% of the total in the Joinville Island and West Areas. Postlarval *T. macrura* ranked second in abundance in the West, Elephant and South Areas where it constituted, respectively, 32% 16% and 18% of total mean abundance. In the Joinville Island Area postlarval *T. macrura* comprised only 9.5% and ranked fourth after postlarval (16%) and larval krill (9.6%).

Zooplankton Assemblages (Table 4.6A; Figure 4.14A)
Cluster analysis was applied to 36 taxa present in at least 23% of samples. Of note here is the diversity of frequently occurring, but not particularly abundant, taxa represented in the area of the 2007/08 survey. The analysis yielded three groupings, roughly conforming to coastal, intermediate and oceanic assemblages, which are recurring features of the Antarctic ecosystem during summer months. Cluster 1, the coastal assemblage, present at 11 stations, was largely associated with Weddell Sea shelf water influence in the southeastern Bransfield Strait. Dynamic height plots and surface drifter tracks indicate that this region was one of gyral circulation and retention (Chapter 1). The oceanic group, Cluster 3 was represented at 38 stations, 24 of which were associated with ACC and ACC- derived waters over and north of the island shelves. Here its distribution conformed to the meandering transport and subsequent offshore deflection of surface drifters around the Shackleton Fracture Zone. The remainder of this group occurred at stations extending along central Bransfield Strait suggesting the intrusion and mixing of waters from west of the South Shetland Islands with subsequent northeast flow towards the Weddell Sea. Intermediate Cluster 2 occurred at 37 stations, 29 of which were around the South Shetland Island shelf area and south of Elephant Island. The remaining 8 were offshore in the lee of the Shackleton Fracture zone.

Mean and median zooplankton abundance values within and between the clusters were fairly similar; means ranged from 880-1610 per 1000 m^3 and medians from 762-1284 per 1000 m^3. Lowest values were associated with Cluster 3, the largest with Cluster 2. Cluster composition and abundance values, by species, can be found in Table 4.6. Coastal Cluster 1 was largely comprised of the copepods *Pareuchaeta sp.*, "others", *C. acutus* and *M. gerlachei* and larval krill, all of which were represented by unusually similar concentrations (11-18% of total mean abundance). It included significantly greater concentrations of larval krill, larval *T. macrura*, *Limacina* spp., barnacle larvae, radiolaria and sipunculids than the other two groups (ANOVA, P<0.05). This composition suggests a mixture of Weddell Sea and Bransfield Strait fauna that was quite different from the other groups (PSI=47 and 54). Intermediate Cluster 2 was dominated by *M. gerlachei*, "other" copepods, *C. acutus* and postlarval *T. macrura* which together accounted for 78% of the total mean abundance. The notable aspect of this group was that included significantly fewer postlarval krill than did the others (P<0.01). Cluster 3, with modest copepod and chaetognath abundance and elevated numbers of postlarval krill and *Thysanoessa macrura*, was not "oceanic" in its composition or abundance. It resembled more an offshore expansion of the typical Bransfield Strait assemblage but split roughly in the middle by Cluster 2. The dissimilarity of Clusters 2 and 3 is indicated by a relatively low PSI= 62.

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Diel Abundance Differences

Only the copepod *Metridia gerlachei* and euphausiid *Euphausia frigida* demonstrated significant diel catch differences (night vs. day, P<0.001) due to vertical migrations. Interestingly, ostracods were more abundant at twilight than during day or night (P<0.05).

Water Zone Affiliations

Because of the expansive offshore distribution of typically Bransfield Strait zooplankton taxa there were not many clear associations between zooplankton species and water types. *Salpa thompsoni* and amphipods *Themisto gaudichaudii* and *Cyllopus magellanicus* had significantly greater concentrations in Type 1 (ACC) water vs. Type 4 (Bransfield Strait) and Type 5 (Weddell Shelf) waters (ANOVA, P<0.05). Postlarval *T. macrura* were less abundant in Type 5 vs. other types. On the contrary, larval *T. macrura* and larval krill were significantly more abundant in Weddell Shelf water than other waters (Type 5 vs. Types 1, 2 and 4; P<0.05). The siphonophores *Diphyes antarctica*, sipunculids and barnacle larvae were also more abundant in Type 5 water (P<0.05) and suggest a Weddell source region. However, as previously noted for krill larvae, it is possible that some of these taxa were advected into the area by clockwise circulation within Bransfield Strait and retained by fronts and eddies associated with the meeting of Bransfield Strait and Weddell waters (Chapter1).

4.4.2 Survey A Between-Year Comparisons:

4.4.2.1 Krill:

Postlarvae (Tables 4.7, 4.8A, 4.9A, 4.10A; Figure 4.15)

Within the 1992-2008 data set mean abundance of postlarval krill in the Elephant Island Area in January 2008 was second to the peak January value observed in 2003 while the median value for January 2008 ranked third behind the highs in 2003 and 2007. These large values result from strong recruitment success of the 2006/07 year class and marks the third successive year of good recruitment. The sequence of year class success over the past 20 years can be seen through length-frequency distribution patterns. In the early 1990s, the proportions of one-year-old juvenile lengths (20-35 mm) from the previous year's spawn were separated by four years between strong recruitment from the 1990/91 and 1994/95 year classes. After this modest recruitment success occurred for another two years (1995/96 and 1996/97) followed by two years with no recruitment. This pattern recurred after 2000 with three successive years of good recruitment and increasing abundance, followed by two years with little recruitment and decreased abundance. Three back-to-back years of good recruitment and population increase also occurred after 2005. Periods favoring recruitment success also appear to involve population movements within the AMLR survey area. Observational data (Siegel et al, 2002) and R2 recruitment indices, based on proportions of two-year-old krill length classes (i.e., 35-45 mm; Siegel, pers com), suggest that juveniles were under-represented during 2001 and 2006 (Fig. 4.15) due to their distribution primarily in southern

Bransfield Strait, south of the AMLR survey effort. Under-sampling of the juveniles was suspected during both of those years based on the proportions of advanced female maturity stages and larval concentrations observed during the 2000 and 2005 surveys. In contrast, by the third successive year of good recruitment (2003 and 2008) older krill (i.e., >50 mm) were rarely collected, suggesting that as the population builds up the age/length/maturity distributions expand offshore, with the largest individuals being outside of the survey area. As indicated in Table 4.9, abundance attributes within the Survey A areas each year track the distributional shifts: greatest concentrations and index of dispersion values characteristic of juveniles occurred in the South and/or Joinville Island Area following the first year of good recruitment; in subsequent years greatest concentrations and patchiness occurred in the Joinville and Elephant Island Areas. Such spatial expansion may result from a number of factors including hydrographic conditions (e.g., movements of the ACC, flow dynamics within Bransfield Strait), competition for limited food resources and population dispersal.

Juveniles contributed over 51% of the total krill collected in the Elephant Island Area during Survey A and indicate extremely strong recruitment success from the 2006/07 year class. This proportion rivaled that of the 1994/95 year class, represented by 55% juveniles in summer 1996, which yielded the highest R1 value (0.622) thus far in the long-term data set. However, the strong possibility that adult krill were under-sampled during January 2008 in conjunction with the depleted adult population sampled in 1996 suggests caution in ascribing a similarly large recruitment value for the 2006/07 year class. Among mature krill, a relatively low 25% of females in the Elephant Island Area were in advanced reproductive stages suggesting a delayed spawning period and potentially reduced recruitment success for the 2007/08 year class.

Larvae (Tables 4.3; 4.7A)

Despite a possibly delayed spawning period, larval krill were relatively abundant across the survey area, with overall mean and median values (33 and 6.2 per $1000m^3$) substantially greater than those during January 2007 (9.2 and 0.1 per $1000m^3$). Among the four areas, the Joinville Island Area had largest larval krill concentrations, making this the fourth time out of the past eight years it has been sampled that it has yielded peak concentrations during January surveys. In comparison, peak larval concentrations occurred in the Elephant Island Area three years and in the West Area one year. This could be the consequence of various factors: earlier and/or elevated spawning intensity in Bransfield Strait; southeastward advection by cyclonic flow within Bransfield Strait from deep basins and slope regions where they were spawned with subsequent concentration by fronts, or eddies between Weddell Sea and Bransfield Strait waters. Drifter buoy tracks and hydrographic conditions monitored during Survey A support the latter hypothesis (Chapter 1).

4.4.2.2 Salps:

Salpa thompsoni and *Ihlea racovitzai* (Tables 4.7, 4.10A)

Mean abundance of *S. thompsoni* in the Elephant Island Area during Survey A 2008 was the lowest in the long-term data set while the median value, similar to Survey A 2007, was similar to the low in 1995. While the maturity stage composition in the West Area was typical for summer, the large proportions of solitaries in the Elephant Island Area (20% of total salps) was unusual and reported only once before, during 1997 Survey A, a period marked by unusually warm sea surface temperatures. The significant association between *S. thompsoni* abundance and ACC water during Survey A conforms to the pattern observed since 2000 and differs from previous years when Weddell water was an important source of salps into the survey area. The paucity of *S. thompsoni* over the past two seasons has been associated with Niño neutral and La Niña periods and possibly results from a weakened Weddell Sea gyre and diminished supply from the southeast Atlantic via warm core rings.

The overall mean and median abundance values of *I. racovitzai* were similar to the lows observed in 2003 and reflect reduced Weddell Sea water influence across the survey area.

4.4.2.3 Nekton and Micronekton (Tables 4.7, 4.10A, 4.11A, 4.12A):

As during all but the "salp years" of 1994, 1998 and 2005, copepods numerically dominated the zooplankton assemblage during Survey A. Mean and median copepod abundance values, and percentage of total mean zooplankton abundance, in the Elephant Island Area were similar to those in January 2007. Copepod abundance in 2007 and 2008, although less than half the values of 2006, were relatively high compared to January 2003-2005. The relative order of mean and median abundance of *Metridia gerlachei*, "other" copepods, *Calanoides acutus* and *Pareuchaeta* spp. has been fairly consistent over the past three years, but the relative order 2008 was most like that of 2006. Actual proportions represented by each copepod taxon vary greatly between years as reflected by the highest PSI values of 56-57 from comparisons between 2008 and 2001, 2004, 2005 and 2007.

The overall rank order of abundance of dominant taxa in the Elephant Island Area (copepods, postlarval *T. macrura,* postlarval *krill* and larval krill) is most similar to that observed in 2007. This is born out by the relatively high PSI value (84) from comparisons of percent contributions to total zooplankton abundance. Mean and median abundance of postlarval *Thysanoessa macrura* were the highest recorded, surpassing the former highs observed in 2003 and 1998. In contrast, larval *T. macrura* was relatively scarce with mean and median abundance values approaching the lows also observed in 2003 and 1998. It is possible that during periods characterized by offshore expansion of intermediate zone taxa the larval stages of *T. macrura*, and possibly those of larval krill¸ are displaced offshore into unsampled waters. The relative abundance of *S. thompsoni* was the lowest recorded during AMLR January surveys.

4.4.3 Survey D and South Orkney Islands:

4.4.3.1 Krill:

<u>Postlarval Frequency, Distribution and Abundance (Tables 4.1B; Figure 4.1B</u>)

South Orkney Islands

Postlarval krill were present in 32 of the 37 samples collected around the South Orkney Islands (86%) with overall mean and median abundance of 175 and 5.0 per 1000m^3, respectively. Mean and median abundance values for the South Orkney Islands can be found in Table 4.1. While krill were equally frequent over the North and South Areas, their mean and median abundance (218 and 20 per 1000 m^3) as well as patchiness (ID=816) over the expansive southern shelf were greater than in the northern shelf area (104 and 1.8 per 1000 m3 mean and median; ID=575). Greatest concentrations (864-1528 per 1000 m^3) were at four stations over or adjacent to the shelf break (1000 m isobath): one of these was adjacent to the narrow island shelf break northwest of the island chain where factory ships were actively fishing; one was offshore to the west and another at the shelf break to the east; the fourth was over the south shelf. Drifter tracks and dynamic height plots (Chapter 1) indicate counterclockwise (anticyclonic) flow around the island chain that may have facilitated krill concentrations along the narrow shelf breaks immediately west, east and north of the islands while a small eddy over the southern shelf may have concentrated krill at its periphery.

Transit

Krill were present at all seven stations sampled between the South Shetland and South Orkney Island Areas. Two samples taken during the eastward transit contained modest concentrations (35 and 120 per 1000m^3) while catches at two of the five westward transit stations were ca. 4X larger (231 and 476 per 1000 m^3). The mean abundance value here (124 per 1000m^3) was midway between those of the Elephant Island and South Orkney South Shelf Areas.

South Shetland Islands

Overall krill catch frequency (58 of 65 samples, 89%) and abundance values in the South Shetland Island Area were 185 and 8.3 per 1000m^3 mean and median, respectively. Mean and median abundance values for each Area in Survey D can be found in Table 4.1. However, here there were more substantial differences in distributional attributes between the two portions. Krill were broadly and evenly distributed across the Elephant Island Area, present in 40 of the 44 samples (91%) with mean and median abundance values of 79 and 14 per 1000 m^3. Catch frequency in the South was slightly lower (18 of 21 samples, 86%) but the larger mean and smaller median values (406 and 3.2 per 1000 m^3) reflected a much patchier distribution, indicated by a substantially larger ID (3089 vs. 363). Largest concentrations in the Elephant Island Area (2891 and 3240 individuals, 768 and 832 per 1000 m^3) were located offshore northeast of Elephant Island. Largest concentrations in the South Area (4700 and 18823 individuals, 1482 and 5176 per 1000 m^3) were in southwestern Bransfield Strait in the vicinity at which cyclonic flow is deflected to the northeast.

Length and Maturity Stage Composition (Tables 4.2B; Figures 4.2B, 4.3)

South Orkney Islands

Krill lengths in the South Orkneys Area ranged from 18-52 mm. The median and modal lengths were 29 mm and 80% of krill were $\leq$ 35 mm reflecting a predominantly young population (i.e., one-year-old individuals). Maturity Stage Composition data can be found in Table 4.2. Accordingly, the overall catch was dominated by juveniles (66%). The age/maturity/length structure differed between the northern and southern shelves with substantially greater proportions of small juveniles in the south (71% $\leq$ 30mm, 73% juveniles). Only 6% of the krill over the south shelf were mature. In contrast, the length-frequency distribution of krill over the north shelf was bimodal with 29 mm and 42-47mm primary and secondary modes, respectively, reflecting contributions of one-year-old (ca. 64%), two-year-old and older individuals. Juveniles comprised 54%, immature stages 20% and mature stages 26%, the latter of which was comprised primarily of females in early reproductive stages (3a-b, 22% of total). Fully mature males (3b) made up 1% of the North Shelf catch, few of the mature females had mated.

Based on cumulative percent curve comparisons, the krill length-frequency distribution from the southern shelf most resembled that of the Joinville Island Area during Survey A (D_{MAX} = 8.8) while that from the northern shelf was most similar to the South Area during Survey A (D_{MAX} = 11.3). Cumulative percent curves derived from the proportions of each maturity stage also indicate that krill from the South Orkney Island southern shelf were quite similar to those in the Joinville Island Area (D_{MAX} =3.8), while krill from the northern shelf more resembled those from the Elephant Island Area (D_{MAX} =14.7) during Survey A.

Transit

Krill from the seven transit samples collected between the South Orkney Islands and South Shetland Islands were of a more limited size range (20-48mm) and somewhat larger median length (34 mm). The length-frequency distribution was bimodal with more or less similar proportions centered around 28mm and 38mm (i.e., one- and two-year old) modes. Maturity Stage Composition data can be found in Table 4.2. Accordingly, juveniles constituted 40% and immature stages 43% of the catch. The 17% comprised by mature stages were primarily females in early reproductive stages (3a-b). The length-frequency distribution was most similar to that in the South Orkneys Island north shelf area (D_{MAX} =15.2). The maturity stage composition was most similar to those in the Elephant Island and South Areas (D_{MAX} =11.9 in both cases) during Survey A.

The length-frequency and maturity stage composition results from the South Orkney Islands and Transit samples are in accordance with drifter tracks that show (1) eastward flow at 62^{o}S from the southern

Elephant Island-eastern Joinville Island Area to the South Orkneys South Shelf Area, (2) northeastward flow in the Bransfield Strait from the South Area into the Elephant Island Area and (3) northeastward flow from east of Elephant Island toward the northern shelf South Orkney Islands (Chapter 1). The similarity between krill demographics sampled around the South Orkney Islands during February-March and in the South Shetlands a month earlier supports their advective transport. In this respect it appears that krill located in southeastern Bransfield Strait (Joinville and southeast Elephant Island Areas) during January were more likely to have been advected into the southern shelf of the South Orkney Islands, while krill from western and central Bransfield Strait and the mid- to northeastern Elephant Island Area were more likely to have been advected to the northern shelf of the South Orkney Islands.

South Shetland Islands

South Area krill were represented by a broader size range, 19-57 mm, and had a much larger median length, 41mm, than those in the South Orkney Islands. The length-frequency distribution was bimodal around a 44mm primary mode and 28mm secondary mode reflecting the inclusion of substantially older, larger individuals than were represented to the east. The size range in the Elephant Island Area was similar to that of the South Area, and the median length in the Elephant Island Area was 44mm. Length-frequency distributions in both areas were bimodal with the secondary mode conforming to one-year-old krill (27-32mm). The primary mode was centered around 38-44mm (two-year-olds) in the South Area and 44-48mm (three-year-olds) in the Elephant Island Area. Maturity Stage Composition data can be found in Table 4.2. Almost half (44%) of the Elephant Island krill were $\geq$ 45 mm, compared to 15 % during Survey A, thereby confirming the idea that the older individuals were located offshore and under-sampled at that time. Their appearance during Survey D is explained by seasonal onshore migration (Siegel, 1988).

Overall, juveniles constituted 22%, immature stages 26% and mature forms 52% of krill in the South Shetland Island Area. Mature stages numerically dominated in the Elephant Island portion where they made up 68% of the catch. Juveniles and immature stages were more or less equally represented here (14% and 18%, respectively). Reproductively mature males and females comprised 31% and 37%, respectively, and 56% of the mature females were 3c-e indicating active mating and spawning continuing into March. The proportion of advanced females (3d-e) was only 17%. It is possible that these older krill were undergoing late-season batch spawn after previously spawning offshore. Juvenile, immature and mature stages were more evenly represented in the South Area (33%, 38% and 29%, respectively). The majority of mature females here lacked spermatophore packets (14% of total krill) and 18% of those that bore them were in advanced reproductive stages (3d-e, gravid and spent) suggesting the end of the reproductive season here. This conforms to indications during Survey A of an earlier reproductive season in the South than West and Elephant Island Areas.

Distribution Patterns (Figures 4.4B, 4.5B)

Cluster analysis applied to krill length-frequency data from 63 Survey D samples yielded four distinct size/age/maturity groupings represented to varying degrees across the South Orkney Islands and South Shetland Islands.

Two of these, Clusters 1 and 2, had greatest representation around the South Orkney Islands and in Transit samples. Cluster 1 occurred at 18 stations, four of which were in central and eastern Bransfield Strait stations, 12 over or adjacent to the southern shelf of the South Orkney Islandss, and two around the rorthern shelf of the South Orkney Islands. These were predominantly small juveniles (71%) and immature males and females (together 21%); 85% of the individuals were <35 mm. Cluster 2 was present at 13 stations, three in western Bransfield Strait, three adjacent to and east of Elephant Island, four transit stations with moderate krill catches, and three stations scattered around the South Orkney Island shelf break. These krill were predominantly one- and two-year olds with a bimodal distribution around 28 mm and 38-43 mm modes; juveniles and immature stages both contributed 39% and mature individuals 22%. Most of the mature females (20% of the total) were without spermatophore packets (stage 3a) and only 8% were in advanced stages; mature males were scarce.

Cluster 3 was the largest group, represented at 25 stations, 19 of which were around the South Shetland Island. Here they extended northeast from western Bransfield Strait to northeast of Elephant Island. They were also present at six South Orkney Island stations, five encircling the island chain and one over the southern shelf. Like Cluster 2, these had a bimodal length-frequency distribution reflecting one- and two-year old krill, but with larger individuals (42-44 mm) being more abundant. Juveniles made up 14%, immature stages 23% and mature individuals 63% of the total. Overall, mature females and males respectively constituted 41% and 22%; 16% of the females were in advanced maturity stages (gravid or spent). However, as indicated above, the majority of Cluster 3 mature females in the South Orkneys Area were stage 3a and not actively reproductive.

Cluster 4 was located at seven stations, all of which were in the northwest Elephant Island Area, around the Shackleton Fracture Zone. These were primarily (95%) large mature krill >47 mm in length, representatives of 3+ age classes. Mature males (stage 3b) comprised 68% and mature females 24% of the Cluster 4 individuals. Most of these females were actively mating but relatively few (19%) were in advanced reproductive stages (3d-e, gravid and spent).

The length/age/maturity stage composition and distribution patterns of Clusters 1-3 generally agree with the "source" and "sink" locations and advection pathways derived from comparisons of krill demographics in the South Orkney Islands shelf and South Shetland Islands within the context of drifter tracks. Furthermore, their distribution patterns around the South Orkney Islands more or less conform with the varied flow patterns there as depicted by the dynamic height at depth plot (Chapter 1). Cluster 4 krill were minimally represented during Survey A and at that time were included as components of both Clusters 2 and 3. This was presumably due to offshore expansion and mingling of all year classes, with the oldest being furthest offshore. Based on drifter tracks this southern Drake Passage region was characterized by general northeast flow but complicated by numerous meanders and gyres, particularly in the vicinity of the Shackleton Fracture Zone, which would have minimized the advection of the older age classes into the water around the South Orkney Islands. The complex circulation here during the survey period may have facilitated retention of these large, mature krill (as well as larvae spawned offshore), thus allowing their seasonal onshore movement into the South Shetland Island region (Chapter 1).

<u>Larval Krill Distribution, Abundance and Stage Composition (Tables 4.3; 4.4B, 4.5B; Figure 4.6B)</u>

South Orkney Islands

Larval krill were infrequently collected around the South Orkney Islands, present in low numbers in three samples each from the northern and southern shelves. The two largest catches (59 and 164 larvae, 14 and 49 per 1000m^3) were over the trench northwest of the islands, suggesting a source of ACC-derived water to this region. Mean and median larval krill abundance values (2.0 and 0 per 1000m^3) were quite low, with mean abundance in the North Shelf Area an order of magnitude greater than in the South (4.6 vs. 0.5 per 1000m^3). All of the larvae were early calyptopis (stage C1 92%, C2 8%). In conjunction with the overall krill maturity stage composition described above for the South Orkney Island Area, these results suggest that this was not a source of krill production during the 2007/08 field season.

Transit

Larval krill were present in five of the 7 transit samples (71%), with relatively large concentrations (375-4275 individuals, 77-1160 per 1000 m^3) at three stations. One of these was collected on the eastward transit northwest of the island shelf; the other two were collected on the westward transit at stations closest to the Joinville-Elephant Island Area. The overall mean and median values (205 and 8 per 1000m3) were one to two orders of magnitude greater than to the east. As in the region of the South

Orkney Islands, all of the larvae were C1 and C2 stages (96% and 4%, respectively). Surface drifter tracks indicate that the transit locations with elevated larval krill abundance were associated with circulation patterns (gyres and fronts) that possibly aided retention and limited advective transport into the South Orkney Islands region.

South Shetland Islands

Larval krill were in 71% of the South Shetland Islands samples, but the overall mean and median values here (95 and 5 per 1000 m^3) were almost half those in the Transit samples. Greatest mean concentrations were in the Elephant Island Area (116 vs. 51 per 1000 m^3) due to four large catches (155-2930 per 1000 m^3) over and adjacent to the eastern Bransfield Strait basin. Larval abundance values and maturity stage composition can be found in Tables 4.3 and 4.4. However, the median value was larger in the South Area (13 vs. 4 per 1000 m^3) due to the greater frequency of occurrence (86% vs. 64% of samples) and elevated concentrations at five stations (101-191 per 1000 m^3) over or adjacent to the western Bransfield Strait basin. Virtually all of the larvae from the Elephant Island Area were C1 while those in the South Area included more advanced calyptopis stages: C1, 82%; C2, 15%; and C3, 2%. The presence of older larvae in the South Area compared to the Elephant Island Area was also observed during Survey A and could result from differences in advection and retention within the two areas.

4.4.3.2 Salps:

Frequency, Distribution and Abundance (Tables 4.4B, 4.5B; Figure 4.7B)
Like larval krill, *Salpa thompsoni* were infrequently collected around the South Orkney Islands and, when present, were generally fewer than five individuals. Salps were caught at six stations, five of which were offshore of the island shelf. They were also present in two of the Transit samples. Only one catch made southwest of the South Orkney Island shelf was relatively large (474 individuals, 126 per 1000 m^3). The overall mean values for the South Orkney Island and Transit Areas were, respectively, 3.5 and 0.2 per 1000 m^3. *Ihlea racovitzai* was even rarer than *S. thompsoni*, with one individual caught northeast of the island shelf and another at the westernmost Transit station.

To the west, *S. thompsoni* was present only in the Elephant Island Area. Here they were collected at 31 stations (71%) with mean and median abundance values of 28 and 1.3 per 1000m^3, respectively. Almost all of the larger catches were offshore of the island shelf and the five largest concentrations (104-239 per 1000m^3) were near the Shackleton Fracture Zone, possibly retained within gyral circulation there. Small numbers of I. *racovitzai* were present in two samples each from the Elephant Island and South Areas.

The rarity of *I.* racovitzai suggests little input of Weddell shelf water into either the South Orkney Islands or South Shetland Islands. Furthermore, the general paucity of S. *thompsoni* anywhere but offshore of Elephant Island suggests minimal influence of the ACC. The one large salp catch southwest of the South Orkneys possibly resulted from an advective pulse from the Elephant Island Area and/or accumulation at a frontal zone.

Length and Maturity Stage Composition (Figures 4.8)
In contrast to Survey A, the aggregate stage of *S. thompsoni* in the Elephant Island Area constituted the vast majority of individuals (94%). Their lengths ranged from 4-51mm but 80% were <10mm and represent recent budding activity by the solitary stage. This recent production explains a six-fold abundance increase in the Elephant Island Area over the past month. With a 40% increase, the solitary stage was also slightly more abundant than during Survey A.

Like Survey A, the solitaries were represented by a broad polymodal size range (4-113mm). The abundance peak of small solitaries (19% of individuals <8mm) results from recent production by the aggregate form. However, 54% of the solitaries were reproductive sizes $\geq$60mm. These individuals explain the recent aggregate release in surface waters. As during Survey A, the presence of the large solitaries may have been facilitated by shoaling of the UCDW (as indicated by the 1.8^{o}C isotherm) into depths fished by the IKMT offshore of Elephant Island. However, elevated abundance and reproductive activity of solitaries typically occurs during spring and early summer months (Foxton, 1966) suggesting that this is an abnormally late period of aggregate production. Remarkably low concentrations of aggregates during January and seasonally delayed chain production by solitaries in February-March could possibly have resulted from the extremely harsh weather conditions during austral Spring 2007 (**Cite Mike Goebels' report discussing weather and fur seal survival)**.

4.4.3.3 Zooplankton and Micronekton Assemblage:

Overall Composition, Abundance and Distribution Patterns (Tables 4.4B, 4.5B; Figures 4.9B, 4.10B, 4.11B, 4.12B, 4.13B

While total mean zooplankton abundance values were fairly similar around the South Orkney Islands and South Shetland Islands (1862 and 2177 per 1000m3, respectively) their overall distribution, as well as distributions of the more abundant taxa, were much more uniform across the South Orkney Islands compared to the South Shetland Islands (ID= 623 vs. 3036). This could result from reduced hydrographic complexity aound the South Orkney Islands. Copepods were the dominant category in both island areas and were represented by fairly similar mean and median abundance (respective means 1282 and 1347 per 1000 m^3; medians 882 and 634 per 100 m^3). They also contributed fairly similar proportions of total mean zooplankton abundance (69% and 62%, respectively). Both areas were numerically dominated by Metridia *gerlachei* which comprised, respectively, 30% and 33% of total mean abundance. *Calanoides acutus* was the second most abundant copepod in the South Orkneys (20%) while "other" copepods ranked second in the South Shetlands (13%). Mean postlarval krill abundance values were similar in the both areas, and this value ranked second to copepods in the South Orkney Island Area. Postlarval *Thysanoessa macrura* was 3X more abundant in the South Shetlands and so ranked second to copepods there and third behind krill in the South Orkneys. Beyond these three categories and chaetognaths (rank 4 in the South Orkneys, 5 in the South Shetlands) the taxonomic differences between the two areas become more obvious. Notably, mean abundance of larval krill ranked 4, and that of *S. thompsoni* ranked 7, in the South Shetlands but, as reported above, both were comparatively rare in the South Orkneys. Species composition values can be found in Tables 4.4 abd 4.5. *Euphausia frigida* and amphipod *Themisto gaudichaudii* were also relatively abundant in the South Shetlands but not well represented in the South Orkneys. In contrast, radiolaria, siphonophores and the amphipod *Primno macropa* were among the more abundant components of the South Orkneys assemblage, but not so numerous in the South Shetlands. Larvae of the decapod *Acanthophyra pelagica* and mysids were also frequent and/or relatively abundant taxa in the South Orkneys compared to the South Shetlands. However, because of the shared dominance by copepods, postlarval krill, *T. macrura* and chaetognaths PSI values resulting from comparisons of the two assemblages are relatively high (PSI=83).

Zooplankton composition and abundance in the various portions of the South Orkney Islands and South Shetland Islands and Transit samples also showed regional differences. Comparisons of the percent contributions of zooplankton taxa in the five areas yielded PSI values of 73-89. The most similar assemblages were represented in the Elephant Island Area and Transit (89), northern and southern shelves of the South Orkney Islands (86) and the Elephant Island and South Areas (83). These relationships are mirrored by PSI values from comparisons of copepod species abundance relationships which were also most similar in the South Orkney Islands northern and southern shelves (94), Elephant Island Area and Transit (88) and Elephant Island and South Areas (82). These results suggest the importance of mixing processes within vs. between the South Shetland Island and South Orkney Island Areas.

Zooplankton Assemblages (Table 4.6B; Figure 4.14B)

Cluster analysis applied to 35 frequently occurring zooplankton taxa in the Survey D samples resulted in three groupings with more or less coherent distribution patterns. Cluster 1, present at 38 stations, was largely associated with the South Orkney Islands. Here it occurred at 32 of the 37 stations. Cluster 1 was also represented at the two westernmost Transit stations, four stations in southeast Bransfield Strait and one station over the northeast shelf of Elephant Island. The notable characteristic of this assemblage was its species richness, with an average of 23 taxa per sample vs. 6-9 in the other clusters. The five numerical dominants, in ranked order of abundance, were *M. gerlachei, C. acutus,* "other" copepods, postlarval krill and *T. macrura*; together these comprised 67% of total mean abundance. In addition to species richness, the cluster was characterized by significantly greater concentrations of radiolaria, larval *T. macrura*, siphonophore *Diphyes antarctica*, amphipods *Hyperiella* spp. and *Orchomene* spp., pteropod *Clione limacina* and larval decapod *Acanthophyra pelagica* than in Clusters 2 and 3. It also had significantly lower concentrations of the oceanic copepod *Rhincalanus gigas* and amphipod *Themisto gaudichaudii* than those clusters.

Cluster 2 was represented at 45 stations, six of which were in the South Orkney Island Area. Here three were off the northwest shelf break and three extended over the southern shelf. The cluster was also present at four of the five easternmost transit stations. The remaining 35 stations at which Cluster 2 occurred generally conformed to the northeast flow pattern in Bransfield Strait, with subsequent offshore flow between King George and Elephant Islands, around and to the northeast of Elephant Island. The overall distribution pattern is in line with the advective pathways of krill to the South Orkney Island discussed above. Of the three clusters this was characterized by lowest zooplankton abundance and without *M. gerlachei* as the overall dominant species. Indeed, *M. gerlachei* abundance here was significantly lower than in the other groups ($P<0.05$). *Calanoides acutus* and "other" copepods were similarly represented and together made up 50% of total mean abundance. Postlarval *T. macrura* contributed another 18% and krill 8%.

Cluster 3 comprised 26 stations, all but one of which were around the South Shetland Islands. The exception was the easternmost Transit station, northwest of the South Orkney Islands shelf. Half of the stations where Cluster 3 occurred were offshore of the Elephant Island shelf in regions influenced by the ACC (i.e., Type 1 and 2 water). The group was also present at seven stations west and south of Elephant Island and five more in central Bransfield Strait. It was distinguished by strong *M. gerlachei* dominance, which alone constituted 43% of total mean abundance; postlarval *T. macrura* and "other" copepods contributed another 25%. Notable characteristics of this group were its low species richness (an average of six taxa per sample) but elevated zooplankton abundance, largely due to the three dominants along with *E. frigida*, larval krill and S. *thompsoni*, all of which were significantly more abundant here than in the other clusters (ANOVA, $P<0.05$). Greatest mean postlarval krill abundance was also in this cluster, the composition of which conforms to that of the "East Wind Drift".

Diel Abundance Differences

Day-night abundance comparisons made using the South Shetland Island data resulted in many more significant differences than during Survey A. In addition to *Euphausia frigida* and *M*. *gerlachei,* substantially greater nighttime catches occurred for *E. triacantha* and *T. macrura* postlarvae, the copepods *Pleuromama robusta*, *Pareuchaeta antarctica*, *Pareuchaeta* sp., and "other" species, *S. thompsoni*, ostracods, myctophid *Electrona antarctica*¸ total copepods and total zooplankton (ANOVA, $P<0.01$ in all cases). These results are attributed to increased periods of darkness and diel vertical migrations into surface waters with the advancing season.

Water Zone Affiliations

As with Survey A, there were few clear associations between zooplankton taxa and water types in the South Shetland Islands. Again, *T. macrura* larvae and sipunculids were more abundant in Type 5 water ($P<0.05$) than the other types. During Survey D these taxa were joined by larvaceans, *Clione limacina*, *Limacina helicina* and *Limacina* sp. (Type 5 vs. Type 2 and 4 water; $P<0.05$). While larval krill were most abundant in Bransfield Strait (Type 4) water, the difference between this and other water types was not significant. Once more *S. thompsoni* was significantly more abundant in ACC (Type 1) water than in all other types ($P<0.05$). *Rhincalanus gigas, C. magellanicus* and *Primno macropa* all were more abundant in ACC and ACC-derived water (Types 1 and 2) than Bransfield Strait and Weddell (Types 4 and 5) water ($P<0.05$).

4.4.5 Survey D Between-Year Comparisons:

4.4.5.1 Krill:

Postlarvae (Tables 4.7, 4.9)

Mean krill abundance in the Elephant Island during 2008 Survey D ranked third behind the February-March highs recorded in 1996 and 1998 while the median value was double the previous highs recorded in 1992 and 2004. The robustness of the increased population size monitored in 2008 compared to previous years is indicated by the fact that it remains among the top three years despite seasonal reduction in the mean. Like 2008, the high mean values in 1996 and 1998 resulted from seasonal onshore movement of large mature krill, but these were as highly concentrated patches, as indicated by low median and high maximum values. This population build up, like that observed in 2003, is the consequence of three back-to-back years of good recruitment success.

Within the South Area mean krill abundance was the highest recorded since 1998, and like 2002-2005, resulted from seasonal increases in both abundance and patchiness associated with southward migration. The low median abundance value was similar to those in 2002 and 1998 (3.2 per $1000m^3$) and reflect the highly patchy distribution of the generally young individuals sampled there.

As noted above, the krill maturity stage composition in the Elephant Island Area indicates a somewhat lagged seasonal spawning period. However, the proportions of mature females in advanced stages (gravid and spent) during February-March is midway between the lowest values recorded in 1992, 1993, 1998, 2003 and 2005 (<10%) and highest values in 1995, 1997 and 2001 (>90%) and therefore does not necessarily forebode poor recruitment success. That could ultimately depend on the retention of larvae from eggs spawned in Bransfield Strait, and potentially spawned offshore in Drake Passage, by meanders, fronts and eddies indicated by the January-April drifter tracks and subsequent atmospheric-oceanic processes facilitating their onshore transport.

Larvae (Table 4.3)

Despite a somewhat delayed spawning period, the mean and median larval krill values in the Elephant Island and South Areas and along the Transit during February-March 2008 were moderately high with respect to concentrations in individual areas sampled since 2001 and for Surveys A and D since 1996. However, the scarcity of larval stages more advanced than Calyptopis 1 combined with moderate abundance, like Survey D 1999, may not favor recruitment. As noted above, recruitment success most likely will be determined by conditions during late-summer and autumn months.

4.4.5.2 Nekton and Micronekton (Tables 4.7, 4.10, 4.11, 4.12):

Copepods numerically dominated the zooplankton assemblage in the Elephant Island Area with moderately high mean and median values similar to those in 1996 and 1999. This is the first February-March survey effort since 2005; the strong representation by copepods differed greatly from that time, when *S. thompsoni* concentrations were elevated to levels that rivaled copepods. The proportion of total mean zooplankton abundance attributed to copepods (65%) was similar to that observed in 2001, but substantially less than during the 2002-2004 surveys when they made up 74-83% of total mean zooplankton abundance. However, the relative abundance of dominant copepod taxa (*M. gerlachei,*"others" and *C. acutus*), was most similar to that in 2003. As during 2001 and 2003, postlarval *T. macrura* ranked second to copepods in mean abundance. While sharing similar proportions of total mean abundance with 2001 (15%), the actual abundance values and even distribution across the area were most like 2003. The extremely low concentrations of larval *T. macrura* seen in 2008 are a recurring phenomenon, seen also during the 1998, 2003 and 2005 February-March surveys. These are likely related to latitudinal movements of the ACC as greatest concentrations of these larvae are typically found offshore and, along with larval krill, possibly associated with UCDW within the ACC. PSI values support the similarity between the overall zooplankton assemblage in 2008 and those in 2001 (85) and 2003 (88)

4.4.6 Survey A and D 2008 Comparisons:

4.4.6.1 Krill:

Postlarvae (Tables 4.2, 4.5, 4.7, 4.9; Figures 4.2, 4.3)

Mean krill abundance in the Elephant Island Area decreased by ca. 30% while the median value was unchanged between Surveys A and D. This was associated with greatly reduced abundance of juveniles, which dropped from 52% to 14% of the catch, and substantially decreased patchiness later in the season. Mean and median abundance values for each Area can be found in Table 4.5. In the South Area however, mean abundance increased by an order of magnitude and patchiness substantially increased. Here juvenile and immature stages remained the dominant component across the survey period, indicating that the abundance increase was associated with seasonal southward migration, particularly of the younger stages. Similarly, appearance of the larger 3+ age classes in the Elephant Island Area during Survey D would have resulted from seasonal migration there from offshore waters not sampled the previous month. Under-sampling of these krill was suspected during Survey A, and presence of the "missing" age classes during Survey D confirms the suggested offshore expansion of age/length/maturity stages during periods favoring recruitment success and population increase. It was previously suggested that such spatial expansion might result from a number of factors including hydrographic conditions (e.g., movements of the ACC, flow dynamics within Bransfield Strait). Plots of temperatures at 350 m depth over the 2001-2008 period indicate movements of core waters of the ACC ($\geq 2^{o}$C) and the ACC Southern Front (1.8^{o}C) that are consistent with this suggestion with their onshore location in 2001 and 2005/2006 with movement offshore across subsequent years.

The proportions of advanced female maturity stages in the Elephant Island during both surveys suggest a delayed seasonal spawning effort there. Maturity stage composition during both surveys also suggest an earlier initiation and termination of seasonal reproductive activity in the South compared to Elephant Island Area where actively mating individuals were well represented in early March. These observations could explain regional differences in larval abundance and maturity stage composition.

Larvae (Table 4.3; Figure 6)

Mean larval krill abundance increased somewhat over the survey period, 4X in the Elephant Island and 30% in the South Area, while the median values decreased slightly in both areas. Calyptopis 1 larvae remained the overwhelming dominant stage in the Elephant Island Area suggesting continuous advective loss across the survey period. The South Area collections included greater proportions of older larvae (primarily C2) during both surveys, but again the dominance of C1 larvae suggests advective loss from this area. Seasonal changes in larval distribution patterns together with results from the South Orkney Island survey suggest that larvae might have been transported to the northeast from the central and eastern portions of the Elephant Island Area. However, persistent gyral circulation within the Joinville Island Area might have retained and concentrated larvae advected there from the west. Few larvae appeared to have been lost to the South Orkney Islands. Furthermore, larvae spawned by the large, more fecund krill in offshore areas during January-February might have been retained by the complex meandering flow and gyres that persisted there, enhancing the possibility of subsequent onshore transport in late summer.

4.4.6.2 Nekton and Micronekton (Tables 4.5, 4.7, 4.10, 4.11, 4.12):

The Elephant Island and South Areas both had modest increases in mean and median zooplankton abundance between Surveys A and D and, when pooled, overall zooplankton abundance in the two areas was significantly greater than during January (ANOVA, $P<0.05$). Significant seasonal abundance increases were demonstrated by the copepods *R. gigas*, *Haloptilus* sp. and *Heterorhabdus* sp., chaetognaths, *E. frigida, S. thompsoni*, *Themisto gaudichaudii*, larvaceans and larval *Electrona antarctica* ($P<0.05$). Increased numbers of *E. frigida*, and to some extent salps, during Survey D could be attributed to longer nighttime hours. Significant seasonal abundance decreases occurred for the pteropods *Clione limacina*, *Limacina helicina*, *Limacina* sp., and *Spongiobranchiae antarctica*, barnacle larvae and numbers of taxa represented in samples.

In terms of overall taxonomic composition, the Elephant Island assemblages did not change much between the two surveys as indicated by a high PSI=91. This was due to fairly stable contributions by copepods, postlarval krill and *T. macrura*, larval krill and chaetognaths across summer months. The South Area assemblage underwent a more substantial change (PSI=81) due in large part to the substantial increase in postlarval krill relative to copepods during Survey D. Copepod abundance relationships underwent greater seasonal change in the Elephant Island Area as indicated by PSI=82 vs. 88 in the South Area. This was largely due to increased proportions of *M. gerlachei* and *R. gigas* relative to "other" species in the Elephant Island Area.

4.5 AMLR 2008 Cruise Summary:

1. Postlarval krill mean and median abundance values in the Elephant Island Area during Surveys A and D 2008 were among the highest since 1992, rivaling or exceeding peaks recorded in January-February 2003 and 2007 and February-March 1992, 1996, 1998 and 2004. These large values result from: (a) population buildup following three back-to-back years of good recruitment success, particularly from the recent 2006/07 year class; (b) expansive northward distribution of one- and two-year-old krill during Survey A; and (c) seasonal southward migration with widespread distribution of older (3+ year-old) krill in the area during Survey D. Three successive years of good recruitment and population growth also occurred during 2000-2003.

2. Population growth resulting from good recruitment during 2000-2003 and 2005-2008 was associated with progressive offshore expansion of krill age/length/maturity classes over the three-year periods. During the first year (2001 and 2006), newly recruited juveniles were likely under-sampled due to distributions primarily in coastal waters south of the survey area; during the third year (2003 and 2008), older mature forms were likely under-sampled due to distributions primarily offshore of the survey area. These population expansions and contractions appear related to latitudinal movements of the Southern Front and core waters of the ACC as indicated by temperature at depth plots generated from AMLR surveys. Such movements have complex ecological significance, particularly with respect to feeding, reproduction and hydrographic processes affecting advection, retention, and population dispersal. They also have consequences with respect to adequately monitoring krill population demographics and biomass.

3. During both Surveys A and D there were indications of (a) earlier reproductive activity in Bransfield Strait vs. Elephant Island and (b) seasonally delayed reproduction in the Elephant Island Area. However, the latter may be biased by the offshore distribution of the older, more fecund animals during Survey A. Nonetheless, larval krill abundance was moderately high both surveys. Greatest concentrations and range of developmental stages in the Joinville Island Area during January were likely due to transport within Bransfield Strait and retention and concentration by circulation in its southeastern portion. Given the persistence of sluggish flow there through April, indicated by drifter buoy tracks, the relatively abundant larvae could presage one more year of moderate to good recruitment. The same applies to larvae potentially spawned offshore in areas characterized by meanders, fronts and eddies. Ultimately, recruitment of the 2007/08 year class will be dependent on atmospheric-oceanic processes facilitating onshore transport in late-summer and fall and favorable overwintering conditions.

4. Comparisons of krill demographics and postlarval and larval abundance between the South Orkney Islands, South Shetland Islands and Transit samples indicate that, during 2008, the South Orkney Islands were a "sink" for, rather than reproductive "source" of, krill. Although the catch frequency and abundance of postlarval krill were fairly similar between the areas, the majority of the krill around the South Orkney Islands were one-year-old juvenile and two-year-old immature stages and very few of the

mature individuals (only 13% of total krill) were advanced reproductive stages. Larval krill were rare. A near shore trench and counterclockwise flow around the island chain may have facilitated krill concentrations along the narrow shelf breaks immediately west, east and north of the islands in the vicinity of krill harvesting activity.

5. Differences in krill length-frequency distributions and maturity stage composition within the South Orkney Islands indicate that individuals over the expansive southern shelf may have been advected there from the southern Elephant Island and Joinville Island Areas, while those in northern shelf samples may have been advected from western Bransfield Strait and mid- to northeastern Elephant Island Areas, over the preceding months. These results are supported by the distribution and composition of four krill length/maturity Clusters derived from Survey D data, and are consistent with advective pathways and circulation patterns depicted by dynamic height plots and drifter buoy tracks (Chapter 1).

6. The Elephant Island zooplankton assemblage sampled during 2008 was dominated by copepods (notably *Metridia gerlachei*, "other" small species, *Calanoides acutus* and *Pareuchaeta* sp.), postlarval *Thysanoessa macrura,* postlarval and larval krill and chaetognaths. Although it had a seasonal abundance increase its overall composition did not change greatly over the survey period. This overall composition, characteristic of the coastal "East Wind Drift", was most similar to that sampled during January 2007 and February-March 2003. The salps *Salpa thompsoni* and *Ihlea racovitzai* were comparatively uncommon and limited primarily to offshore and Bransfield Strait areas indicating limited influence, respectively, by core waters of the ACC and Weddell Sea shelf water.

7. As with postlarval krill, total mean zooplankton abundance values were fairly similar between the South Orkney Islands and South Shetland Islands, but their distributions were much more uniform across the South Orkney Islands, most likely due to reduced hydrographic complexity there. Because of shared dominance by copepods, postlarval krill, *T. macrura* and chaetognaths the zooplankton assemblages of the two Island Areas were relatively similar. However, there were obvious regional differences including rarity of larval krill and *S. thompsoni,* reduced occurrence and abundance of Euphausia *frigida* and *Themisto gaudichaudii* and increased occurrence and abundance of radiolaria, siphonophores, *Primno macropa, Acanthophyra pelagica* larvae and mysids in the South Orkneys compared to the South Shetlands.

8. Zooplankton composition and abundance in the various portions of the South Orkney Islands and South Shetland Islands and along the Transit also showed regional differences. The most similar assemblages overall, and most similar copepod species assemblages, were represented in the Elephant Island and Transit Areas, North and South Shelves of the South Orkney Islands and the Elephant Island and South Areas. These results suggest the importance of mixing processes within vs. between the South Shetland Island and South Orkney Island Areas. Results from zooplankton analyses are consistent with those from krill analyses with respect to advective transport between the South Orkney and South Shetland Island Areas.

4.6 Problems and Suggestions:

1. The Joinville Island Area and southern Bransfield Strait have been shown to be important locations of larval, juvenile and immature krill stages yet they remain under-sampled. We highly recommend increased sampling effort in the Joinville Island Area to a level similar to that represented by the South Area (i.e., 1 per 1224 km^2, or 15 stations). Also, it is imperative that at all stations in Bransfield Strait that are not sampled due to ice conditions be replaced by alternative stations near those stations that are not sampled.

2. The results from the 2008 surveys also indicate the importance of sampling waters offshore of the Elephant Island Area and along easternmost Line 1 of the Elephant Island Area to assess (a) demography

of large krill offshore and (b) hydrographic processes affecting krill advection and loss to downstream areas. It would be valuable also to survey the coastal waters of Gerlache Strait during January to evaluate the importance of this as a nursery for juvenile krill. It would be especially interesting to survey here during the first years of the recruitment success cycle as dense concentrations here may explain their paucity in the regular survey area.

3. The results presented here also indicate the importance of obtaining krill and zooplankton samples over the two one-month surveys, as they yield information on seasonal population dynamics that are essential for understanding ecosystem structure and function. It is greatly hoped that sampling can continue during two month-long survey efforts each year.

4. One of these days it would be wonderful to replace the old worn out and rusty plankton van.

5. Collaboration among the AMLR scientists should be encouraged and supported. We need more workshops during which the different scientific components can discuss their projects to allow greater understanding, cooperation and collaboration. We also need to seriously engage in one-on-one collaboration on manuscript preparation.

6. We greatly benefited from having ancillary hydrographic data from XBTs and drifter buoys! Hopefully these tools will be engaged on a regular basis into the future!

4.7 Acknowledgments:

It was wonderful to once again enjoy the facilities and personnel of the R/V Yuzhmorgeologiya. Captain Sasha was superb in his command of the ship and crew and in his positive interactions with the scientific party! Thanks to all of the many scientists who, despite the difficulties of being densely packed into living spaces, worked hard together in such a harmonious and congenial manner! Again, it was quite satisfying to have the Santora-Force underway bird and mammal team keeping us informed of the exciting wildlife that surrounds us while we toil away below decks.... often giving us enough time to capture some of these on film!

4.8 References:

Foxton, P. 1966. The distribution and life history of *Salpa thompsoni* Foxton, with observations on a related species, *Salpa gerlachei* Foxton. Discovery Report, 34, 1-116.

Makarov. R.R. and C.J.I. Denys. 1981. Stages of sexual maturity of *Euphausia superba*. BIOMASS Handbook 11.

Siegel, V. 1987. Age and growth of Antarctic Euphausiacea (Crustacea) under natural conditions. *Marine Biology* 96: 483-495.

Siegel, V. 1988. A concept of seasonal variation of krill (*Euphausia superba*) distribution and abundance west of the Antarctic Peninsula. Pp. 219-230 *In* D. Sahrhage (ed.) Antarctic Ocean and Resources Variability. Springer-Verlag, Berlin.

Siegel, V. and V. Loeb. 1994. Length and age at maturity of Antarctic krill. Antarctic Science 6: 479-482.

Siegel, V., B. Bergström, U. Mühlenhardt-Siegel and M. Thomasson. 2002. Demography of krill in the Elephant Island area during summer 2001 and its significance for stock recruitment. Antarctic Science 14(2): 162-170.

Table 4.1. AMLR 2008 IKMT station information for (A) Survey A and (B) Survey D. Double lines denote subareas within each Survey.

(A) Survey A

Station	Date	Time Start (Local)	Time End (Local)	Diel	Tow Depth (m)	Flow Volume (m3)	Krill Total N	Krill Abundance N/m2	Krill Abundance N/1000m3
West Area:									
A18-12	18/01/08	0241	0312	T	170	4830.9	153	5.4	31.7
A19-11	18/01/08	0604	0636	D	168	4711.5	7	0.2	1.5
A20-10	18/01/08	0915	0951	D	169	5002.9	297	10.0	59.4
A19-09	18/01/08	1318	1346	D	170	4416.3	71	2.7	16.1
A18-10	18/01/08	1707	1732	D	171	4059.0	75	3.2	18.5
A17-11	18/01/08	2018	2040	D	114	3083.4	222	8.2	72.0
A16-10	18/01/08	1122	1151	D	170	3856.6	21	0.9	5.4
A17-09	19/01/08	0244	0310	N	171	4144.8	0	0.0	0.0
A18-08	19/01/08	0600	0632	D	170	4604.0	21	0.8	4.6
A17-07	19/01/08	1051	1121	D	169	4733.8	26	0.9	5.5
A16-08	19/01/08	1555	1623	D	170	4541.9	55	2.1	12.1
A15-09	19/01/08	1932	2003	D	171	4785.7	23	0.8	4.8
A14-10	19/01/08	2227	2241	D	80	1309.7	4	0.2	3.1
A13-09	20/01/08	0139	0207	N	170	4499.8	17	0.6	3.8
A14-08	20/01/08	0456	0526	D	170	4991.8	1	0.0	0.2
A15-07	20/01/08	0831	0859	D	171	4368.0	178	7.0	40.8
A15-05	20/01/08	1943	2018	D	169	5035.8	81	2.7	16.1
A14-06	20/01/08	2331	0002	D	170	4663.8	642	23.4	137.7
A13-07	21/01/08	0330	0359	N	170	4569.8	4	0.1	0.9
A12-08	21/01/08	0740	0812	D	170	5140.4	1	0.0	0.2
A11-07	21/01/08	1142	1207	D	172	4042.6	1068	45.4	264.2
A11-01	22/01/08	2120	2154	D	169	4589.5	0	0.0	0.0
Elephant Island Area:									
A09-01	23/01/08	0207	0238	T	171	4667.2	145	5.3	31.1
A09-02	23/02/08	0555	0626	D	172	4766.3	84	3.0	17.6
A08-02	24/01/08	2250	2316	N	170	3302.9	71	3.7	21.5
A07-01	25/01/08	0217	0243	N	170	3421.9	20	1.0	5.8
A07-02	25/01/08	0527	0557	D	171	4001.1	2	0.1	0.5
A07-03	25/01/08	0833	0901	D	171	3801.8	30	1.3	7.9
A07-04	25/01/08	1130	1159	D	171	3947.0	38	1.6	9.6
A07-05	25/01/08	1406	1432	D	170	3905.8	104	4.5	26.6
A07-06	25/01/08	1851	1919	D	182	3486.2	48	2.5	13.8
A07-08	25/01/08	2355	0021	N	170	3490.8	8001	389.6	2292.0
A05.5-08	26/01/08	0350	0417	D	171	3909.3	1367	59.8	349.7
A05.5-07	26/01/08	0616	0646	D	169	3845.3	8	0.4	2.1
A05.5-06	26/01/08	0842	0900	D	100	2459.0	343	13.9	139.5
A05.5-05	26/01/08	1047	1112	D	129	2999.2	2	0.1	0.7
A05.5-04	26/01/08	1310	1337	D	170	3837.8	2753	121.9	717.3
A05.5-03	26/01/08	1725	1759	D	171	4116.6	50	2.1	12.1
A05.5-02	26/01/08	2015	2047	D	170	5118.9	29	1.0	5.7
A05.5-01	26/01/08	2306	2341	N	170	4312.2	300	11.8	69.6
A04-01	27/01/08	0356	0425	N	170	3927.7	55	2.4	14.0
A04-02	27/01/08	0658	0730	D	170	4975.4	181	6.2	36.4
A04-03	27/01/08	1000	1037	D	169	5244.7	309	10.0	58.9
A04-04	27/01/08	1229	1259	D	170	4195.3	61	2.5	14.5
A04-05	27/01/08	1701	1732	D	170	4513.6	230	8.7	51.0
A04-06	27/01/08	2118	2150	T	160	4584.3	16	0.6	3.5
A04-07	28/01/08	0005	0037	N	171	4237.8	19	0.8	4.5
A04-08	28/01/08	0311	0343	N	170	4158.0	0	0.0	0.0
A03-08	28/01/08	0601	0635	D	170	5220.0	154	5.0	29.5
A03-06	28/01/08	1007	1042	D	169	4716.3	2	0.1	0.4
A03-04	28/01/08	1352	1422	D	170	3986.8	256	10.9	64.2
A03-02	28/01/08	1938	2010	D	170	4052.3	55	2.3	13.6
A02-05	29/01/08	1353	1427	D	171	5073.7	163	5.5	32.1
A02-06	29/01/08	1921	1954	D	170	4447.9	6	0.2	1.3
A02-07	29/01/08	2233	2302	T	179	3468.8	86	4.4	24.8
A02-08	30/01/08	0155	0223	N	169	4176.5	18	0.7	4.3

(A) Survey A (Contd.)

Station	Date	Time Start (Local)	Time End (Local)	Diel	Tow Depth (m)	Flow Volume (m3)	Krill Total N	Krill Abundance N/m2	Krill Abundance N/1000m3
Joinville Island Area:									
A02-09	30/01/08	0441	0510	D	170	4442.7	1977	75.7	445.0
A02-11	30/01/08	0916	0949	D	170	4273.5	2254	89.7	527.4
A02-13	30/01/08	1244	1317	D	169	4483.0	116	4.4	25.9
A03-14	30/01/08	1634	1702	D	169	4213.4	2767	111.0	656.7
A04-13	30/01/08	1943	2012	D	169	4107.6	8	0.3	1.9
A04-11	30/01/08	2348	0016	N	169	4103.9	1	0.0	0.2
A04-09	31/01/08	0449	0520	D	170	4143.9	1	0.0	0.2
A06-09	31/01/08	0913	0945	D	170	4757.4	5	0.2	1.1
A06-11	31/01/08	1325	1354	D	170	4137.0	0	0.0	0.0
A06-12	31/01/08	1716	1748	D	170	4525.6	0	0.0	0.0
South Area:									
A07-11	31/01/08	2024	2101	D	170	5279.3	3	0.1	0.6
A08-10	31/01/08	2331	0001	T	168	4622.7	91	3.3	19.7
A09-09	01/02/08	0210	0225	N	102	1975.7	8	0.4	4.0
A10-10	01/02/08	0535	0602	D	170	5213.1	4	0.1	0.8
A09-11	01/02/08	0849	0920	D	170	4235.9	1	0.0	0.2
A08-12	01/02/08	1128	1159	D	155	4673.8	1	0.0	0.2
A09-13	01/02/08	1548	1620	D	170	4677.4	105	3.8	22.4
A10-12	01/02/08	1858	1934	D	170	4765.2	5	0.2	1.0
A11-11	01/02/08	2204	2236	T	170	4779.0	4	0.1	0.8
A13-11	02/02/08	0152	0220	N	170	4262.0	33	1.3	7.7
A12-12	02/02/08	0520	0548	D	170	3905.7	3	0.1	0.8
A11-13	02/02/08	0941	1006	D	170	3408.0	2	0.1	0.6
A12-14	02/02/08	1212	1234	D	120	1613.8	103	7.7	63.8
A13-13	02/02/08	1515	1548	D	170	4689.6	1805	65.4	384.9
A14-12	02/02/08	2006	2029	D	172	3675.6	10	0.5	2.7
A15-13	02/02/08	2332	2358	N	170	3894.8	7	0.3	1.8
A14-14	03/02/08	0241	0310	N	170	4137.7	4	0.2	1.0
A15-15	03/02/08	0548	0618	D	170	4332.1	2	0.1	0.5
A16-14	03/02/08	0923	0951	D	169	4048.2	0	0.0	0.0
A17-13	03/02/08	1156	1222	D	176	3768.0	4	0.2	1.1

		Krill Occurrence F(N)	Krill Occurrence F(%)	Total		Krill Abundance N/m2	Krill Abundance N/1000m3
Survey A Total:	N=86	79	91.9	27297	Mean	13.5	80.8
					STD	46.8	275.6
					Median	0.9	5.5
West Area:	N=22	20	90.9	2967	Mean	5.2	31.7
					STD	10.2	60.0
					Median	0.9	5.5
Elephant Island Area:	N=34	33	97.1	15006	Mean	20.1	119.9
					STD	68.0	400.1
					Median	2.5	14.3
Joinville Island Area:	N=10	8	80.0	7129	Mean	28.1	165.9
					STD	42.6	251.6
					Median	0.3	1.5
South Area:	N=20	19	95.0	2195	Mean	4.2	25.7
					STD	14.2	83.7
					Median	0.2	1.0

Table 4.1 (Contd.)

(B) Survey D

Station	Date	Time Start (Local)	Time End (Local)	Diel	Tow Depth (m)	Flow Volume (m3)	Krill Abundance Total N	N/m2	N/1000m3
Eastward Transit:									
DSO-004	17/02/08	1815	1842	D	170	3694.6	130	6.0	35.2
DSO-005	17/02/08	2320	2346	N	171	3660.5	439	20.5	119.9
South Orkney Islands - northern shelf:									
DSO-006	18/02/08	0457	0526	T	171	3866.8	8	0.4	2.1
DSO-031	18/02/08	0745	0810	D	172	3518.6	3	0.1	0.9
DSO-032	18/02/08	1040	1103	D	172	3210.3	57	3.1	17.8
DSO-029	18/02/08	1453	1520	D	173	3585.0	3104	149.8	865.8
DSO-030	18/02/08	1740	1811	D	173	4103.4	22	0.9	5.4
DSO-007	18/02/08	2100	2125	N	174	3339.1	1592	83.0	476.8
DSO-008	19/02/08	0512	0542	T	179	4253.0	309	13.0	72.7
DSO-022	19/02/08	0801	0828	D	169	3453.3	0	0.0	0.0
DSO-042	29/02/08	1001	1030	D	168	3803.2	1	0.0	0.3
DSO-020	19/02/08	1412	1441	D	174	4281.6	1	0.0	0.2
DS0-021	19/02/08	1658	1729	D	171	4185.8	6	0.2	1.4
DSO-009	20/02/08	0841	0908	D	177	3834.1	0	0.0	0.0
DSO-011	20/02/08	1838	1902	D	171	3170.4	2	0.1	0.6
DSO-012	20/02/08	2117	2141	N	173	3429.5	17	0.9	5.0
South Orkney Islands - southern shelf:									
DSO-013	21/02/08	0104	0136	N	170	4201.6	3630	146.9	864.0
DSO-043	21/02/08	0420	0442	T	170	3881.1	38	1.7	9.8
DSO-014	21/02/08	0703	0729	D	168	3811.7	17	0.7	4.5
DSO-044	21/02/08	1009	1035	D	170	3565.5	1102	52.5	309.1
DSO-015	21/02/08	1259	1326	D	169	3614.7	0	0.0	0.0
DSO-016	21/02/08	1718	1749	D	170	4465.2	6824	259.8	1528.3
DSO-017	21/02/08	1941	2009	D	169	3613.6	1	0.0	0.3
DSO-018	21/02/08	2204	2234	N	169	3900.7	2475	107.2	634.5
DSO-019	22/01/08	0109	0141	N	170	4971.4	136	4.7	27.4
DSO-045	22/01/08	0431	0502	N	170	3910.9	1	0.0	0.3
DSO-023	22/02/08	0655	0723	D	172	3928.7	0	0.0	0.0
DSO-024	22/02/08	0927	0954	D	170	4190.3	736	29.9	175.6
DSO-046	22/02/08	1155	1222	D	175	3480.3	71	3.6	20.4
DSO-025	22/02/08	1426	1455	D	171	4416.7	0	0.0	0.0
DSO-026	22/02/08	1819	1845	D	171	3970.2	1	0.0	0.3
DSO-047	22/02/08	2051	2119	T	169	3769.6	128	5.7	34.0
DSO-027	23/02/08	2342	0012	N	170	4061.3	105	4.4	25.9
DSO-048	23/02/08	0304	0332	N	170	4110.7	18	0.7	4.4
DSO-028	23/02/08	0522	0552	T	171	4690.4	18	0.7	3.8
DSO-049	23/02/08	1006	1034	D	170	4243.6	5322	213.2	1254.1
DSO-033	23/02/08	1302	1330	D	171	4000.9	19	0.8	4.7
DSO-051	25/02/08	2104	2131	N	173	3770.8	278	12.8	73.7
DSO-034	26/02/08	1227	1257	N	171	4128.9	195	8.1	47.2
Westward Transit:									
DSO-035	26/02/08	0506	0536	T	170	4154.6	3	0.1	0.7
DSO-036	26/02/08	0947	1010	D	170	3926.9	15	0.6	3.8
DSO-037	26/02/08	1332	1402	D	170	5004.9	1158	39.3	231.4
DSO-038	26/01/08	1943	2008	D	170	3684.0	3	0.1	0.8
DSO-039	26/02/08	2357	0027	N	171	4890.3	2329	81.4	476.2

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(B) Survey D (Contd.)

Station	Date	Time Start (Local)	Time End (Local)	Diel	Tow Depth (m)	Flow Volume (m3)	Krill Abundance Total N	N/m2	N/1000m3
Elephant Island Area:									
D02-01	28/02/08	0225	0251	N	171	3892.1	3240	142.3	832.4
D02-02	27/02/08	2322	2349	N	169	3766.8	2891	129.7	767.5
D02-03	27/02/08	2019	2044	T	171	3559.1	158	7.6	44.4
D02-04	27/02/08	1714	1744	D	173	4652.3	873	32.5	187.6
D02-05	27/02/08	1404	1434	D	172	4284.8	693	27.8	161.7
D02-06	27/02/08	1042	1110	D	171	4851.8	2	0.1	0.4
D02-07	27/02/08	0734	0802	D	170	4379.2	3	0.1	0.7
D02-08	27/02/08	0410	0437	N	170	4779.6	208	7.4	43.5
D03-02	28/02/08	0651	0719	D	170	3795.1	1	0.0	0.3
D03-04	28/02/08	1128	1154	D	170	3604.8	56	2.6	15.5
D03-06	28/02/08	1611	1644	D	171	4531.1	2	0.1	0.4
D03-08	28/02/08	2047	2113	T	169	4079.2	2	0.1	0.5
D04-01	29/02/08	2134	2201	N	170	3805.3	26	1.2	6.8
D04-02	29/02/08	1842	1909	D	170	3859.7	32	1.4	8.3
D04-03	29/02/08	1549	1618	D	170	4958.3	284	9.7	57.3
D04-04	29/02/08	1242	1311	D	169	4067.6	159	6.6	39.1
D04-05	29/02/08	0933	0959	D	169	3794.4	483	21.5	127.3
D04-06	29/02/08	0448	0518	N	170	4026.1	502	21.2	124.7
D04-07	29/02/08	0219	0248	N	169	4432.7	7	0.3	1.6
D04-08	28/02/08	2335	0002	N	171	4433.0	9	0.3	2.0
D05.5-01	01/03/08	0132	0201	N	171	4455.6	59	2.3	13.2
D05.5-02	01/03/08	2210	2235	N	175	3900.2	652	29.3	167.2
D05.5-03	02/03/08	0129	0159	N	170	4956.8	573	19.7	115.6
D05.5-04	02/03/08	0503	0532	T	171	4410.6	67	2.6	15.2
D05.5-05	02/03/08	0757	0820	D	140	3003.3	0	0.0	0.0
D05.5-06	02/03/08	1034	1052	D	102	3799.8	0	0.0	0.0
D05.5-07	02/03/08	1316	1348	D	172	4231.4	0	0.0	0.0
D05.5-08	02/03/08	1621	1649	D	172	3697.9	467	21.7	126.3
D07-01	03/03/08	1704	1733	D	172	4141.0	2	0.1	0.5
D07-02	03/03/08	1415	1445	D	170	4321.7	14	0.6	3.2
D07-03	03/03/08	1118	1142	D	170	3258.3	1	0.1	0.3
D07-04	03/03/08	0806	0830	D	170	3549.7	4	0.2	1.1
D07-05	03/03/08	0452	0521	N	177	4569.0	332	12.9	72.7
D07-06	03/03/08	0139	0206	N	177	4510.9	1045	41.0	231.7
D07-07	02/03/08	2247	2315	N	169	3766.3	93	4.2	24.7
D07-08	02/03/08	1950	2019	T	170	3892.1	66	2.9	17.0
D09-01	03/03/08	2120	2150	N	170	4663.0	3	0.1	0.6
D09-02	04/03/08	0055	0123	N	171	3978.9	685	29.4	172.2
D09-03	04/03/08	0357	0423	N	171	3718.9	24	1.1	6.5
D09-04	04/03/08	0701	0730	D	171	4329.3	0	0.0	0.0
D09-05	04/03/08	1035	1059	D	173	3751.4	10	0.5	2.7
D09-06	04/03/08	1319	1350	D	178	4643.2	117	4.5	25.2
D09-07	04/03/08	1612	1640	D	171	3894.1	23	1.0	5.9
D09-08	04/03/08	1842	1842	D	173	3367.6	166	8.5	49.3
South Area:									
D06-12	05/03/08	0826	0853	D	169	4123.3	13	0.5	3.2
D07-11	05/03/08	0451	0522	N	170	4050.9	1102	46.2	272.0
D08-10	05/03/08	0124	0152	N	173	3971.5	34	1.5	8.6
D08-12	05/03/08	1156	1222	D	154	3895.3	1441	57.0	369.9
D09-09	04/03/08	2222	2233	N	73	1717.0	2	0.1	1.2
D09-11	05/03/08	1512	1542	D	169	4849.7	16	0.6	3.3
D09-13	06/03/08	0413	0439	N	150	4051.1	2736	101.3	675.4
D10-10	05/03/08	1818	1843	D	170	4087.8	0	0.0	0.0

Table 4.1 (Contd.)

Survey D (Contd.)

Station	Date	Time Start (Local)	End	Diel	Tow Depth (m)	Flow Volume (m3)	Krill Abundance Total N	N/m2	N/1000m3
D10-12	06/03/08	0105	0134	N	171	4845.2	1941	68.5	400.6
D11-11	05/03/08	2120	2146	N	169	3882.9	82	3.6	21.1
D11-13	06/03/08	0746	0810	D	170	4203.4	3	0.1	0.7
D12-12	06/03/08	1110	1136	D	169	3854.8	0	0.0	0.0
D12-14	07/03/08	0056	0119	N	141	3169.0	4698	209.0	1482.5
D13-11	06/03/08	1435	1503	D	170	4160.5	6	0.2	1.4
D13-13	06/03/08	2141	2207	N	170	3636.6	18823	879.9	5176.0
D14-12	06/03/08	1826	1852	D	170	3740.7	2	0.1	0.5
D14-14	07/03/08	0523	0551	T	170	4203.5	489	19.8	116.3
D15-13	07/03/08	0820	0850	D	170	4509.2	3	0.1	0.7
D15-15	07/03/08	1232	1301	D	170	4573.1	0	0.0	0.0
D16-14	07/03/08	1559	1628	D	169	4732.9	15	0.5	3.2
D17-13	07/03/08	1914	1941	D	173	4005.9	1	0.0	0.2

		Krill Occurrence F(N)	F(%)	Krill Abundance Total		N/m2	N/1000m3
South Orkney Islands Total:	N=37	32	86.5	1105	Mean	29.9	174.9
					STD	62.9	369.3
					Median	0.9	5.0
North Shelf :	N=14	12	85.7	5122	Mean	18.0	103.5
					STD	42.2	243.9
					Median	0.3	1.8
South Shelf:	N=23	20	87.0	21115	Mean	37.1	218.4
					STD	71.7	422.1
					Median	3.6	20.4
Transit:	N=7	7	100.0	4077	Mean	21.2	124.0
					STD	28.0	164.0
					Median	35.2	35.2
South Shetland Island Area Total:	N=65	58	89.2	45441	Mean	30.5	184.8
					STD	112.5	669.6
					Median	1.4	8.3
Elephant Island Area:	N=44	40	90.9	14034	Mean	13.5	78.9
					STD	28.8	169.2
					Median	2.4	14.2
South Area:	N=21	18	85.7	31407	Mean	66.1	406.5
					STD	188.6	1120.4
					Median	0.5	3.2

Table 4.2. Maturity stage composition of krill collected in the large survey area and subareas during (A) January Survey A and (B) February-March Survey D, 2008. Survey D subareas are the North and South shelf regions of the South Orkney Islands (SOI). Transit region between the South Shetland and South Orkney Island Areas, as well as the Elephant Island and South Areas sampled during Survey A. Overall maturity stage composition of South Orkney and South Shetland Island (SSI) Areas are also presented. Advanced maturity stages are proportions of mature females that are 3c-e (i.e.,developing ovaries, gravid and spent) in January and 3d-3e (gravid and spent) in February-March). Synopses do not include data from stations with exceedingly large catches (i.e., Elephant Island Area A07-08 and South Area D13-13).

(A) Survey A

	Euphausia superba January 2008				
Area	Survey A	West	Joinville I.	Elephant I.	South
Stage	%	%	%	%	%
Juveniles	57.9	54.9	68.8	51.6	48.1
Immature	20.6	11.2	26.4	15.7	30.2
Mature	21.5	33.9	4.6	32.7	21.7
Females:					
F2	2.5	1.1	5.0	0.6	2.6
F3a	7.0	10.9	3.7	9.2	5.2
F3b	4.9	9.7	0.5	8.0	2.0
F3c	1.6	0.3	0.3	3.6	1.2
F3d	0.8	0.0	0.0	1.6	1.4
F3e	0.2	0.0	0.0	0.4	0.6
Advanced Stages	17.9	1.3	5.7	24.5	30.8
Males:					
M2a	7.8	5.4	13.3	3.9	6.8
M2b	6.6	3.1	6.9	7.2	8.3
M2c	3.6	1.6	1.4	3.9	12.5
M3a	1.6	2.3	0.0	1.3	6.6
M3b	5.4	10.6	0.1	8.6	4.8
Male:Female	1.5	1.0	2.3	1.1	3.0
No. measured	4099	1112	423	2062	502

(B) Survey D

	Euphausia superba February -March 2008				
Area	SOI North	SOI South	Transit	Elephant I.	South
Stage	%	%	%	%	%
Juveniles	54.4	72.6	39.8	13.7	33.1
Immature	19.8	21.4	43.0	18.2	37.5
Mature	25.8	6.0	17.2	68.1	29.4
Females:					
F2	4.5	1.3	8.0	2.7	10.1
F3a	17.3	4.9	13.8	8.4	13.8
F3b	4.9	0.7	1.1	8.1	1.2
F3c	0.0	0.1	0.2	14.7	0.9
F3d	0.0	0.0	0.4	4.2	1.3
F3e	0.0	0.0	0.2	2.1	2.3
Advanced Stages	0.2	0.4	3.3	16.9	18.4
Males:					
M2a	7.8	14.5	15.8	5.4	8.5
M2b	1.7	3.5	8.9	3.8	7.6
M2c	5.8	2.0	10.3	6.3	11.4
M3a	2.4	0.2	0.5	4.4	4.4
M3b	1.1	0.1	1.1	26.2	5.4
Male:Female	0.7	2.9	1.6	1.2	1.3
No. measured	546	1220	441	2458	782

Euphausia superba February -March 2008		
Area	SOI	SSI
Stage	%	%
Juveniles	66.0	21.6
Immature	20.8	26.1
Mature	13.2	52.3
Females:		
F2	2.5	5.7
F3a	9.4	10.6
F3b	2.2	5.3
F3c	0.0	9.1
F3d	0.0	3.0
F3e	0.0	2.2
Advanced Stages	0.3	17.3
Males:		
M2a	12.1	6.7
M2b	2.9	5.4
M2c	3.4	8.4
M3a	1.0	4.4
M3b	0.5	17.7
Male:Female	1.4	1.2
No. measured	1766	3240

Table 4.3. Larval krill stage composition and abundance in (A) Surveys A and D (South Shetland Islands), 1996-2008, and (B) individual survey areas, 2001-2008. Only pooled calyptopis and furcilia stages provided for 1996-1999. Individual stages provided for 2000-2008 surveys. R is the proportional recruitment index for each year class. No D surveys were conducted in 2006 and 2007. Subareas during Survey D 2008 include Elephant Island and South Areas (South Shetland Islands), South Shelf and North Shelf of the South Orkney Islands and Transit.

(A) Large Survey Area

Stage %	A96	A97	A98	A99	A00	A01	A02	A03	A04	A05	A06	A07	A08
Calyptopis	100	93	68	100	n.a.	100	70	100	95	99	100	100	99.8
Furcilia	---	7	32	---	n.a.	---	30	---	5	1	---	---	0.2
No. 1000 m-3													
Mean	2.7	15.4	1.0	103.1	n.a.	100.3	12.8	2.4	4.5	11.9	646.6	9.2	33.0
STD	7.5	27.1	4.5	587.4	n.a.	445.2	31.4	7.5	9.4	43.0	2381.8	32.3	64.4
Median	0.0	0.8	0.0	2.6	n.a.	8.1	0.0	0.0	0.1	0.3	2.7	0.1	6.2
Stage %	D96	D97	D98	D99	D00	D01	D02	D03	D04	D05	D06	D07	D08
Calyptopis	86	100	99	97	97	98	85	89	44	85	n.a.	n.a.	100
Furcilia	14	---	1	3	3	2	15	11	56	15	n.a.	n.a.	---
No. 1000 m-3													
Mean	13.9	25.0	1.6	49.8	1374.5	439.2	39.5	2.5	75.2	117.8	n.a.	n.a.	94.8
STD	40.2	81.4	14.1	119.3	4682.1	2320.4	142.1	6.7	340.9	540.7	n.a.	n.a.	391.1
Median	3.0	0.0	0.0	9.0	22.0	6.2	0.0	0.0	13.1	0.0	n.a.	n.a.	4.9
R	0.198	0.120	0.000	0.000	0.573	0.403	0.478	0.001	0.014	0.200	0.230		

(B) Subareas

Survey	A01			A02				A03				A04			
Stage %	West	Eleph	South	West	Eleph	South	Joinvl	West	Eleph	South	Joinvl	West	Eleph	South	Joinvl
C1	17.6	68.4	95.3	50.0	40.3	13.9	5.0	77.7	89.7	100	100	80.0	63.4	60.7	68.2
C2	72.7	22.1	---	50.0	16.3	7.0	2.9	1.9	8.8	---	---	8.3	22.1	7.6	24.9
C3	9.7	9.3	---	---	20.3	---	52.5	20.4	1.5	---	---	---	12.4	8.6	---
Unid.	---	0.2	4.7	---	---	---	---	---	---	---	---	4.3	2.0	0.0	---
Calyptopis	100	100	100	100	76.9	20.9	60.4	100	100	100	100	92.6	100	76.9	93.1
F1	---	---	---	---	6.2	35	38.2	---	---	---	---	---	---	19.3	6.9
F2	---	---	---	---	17.0	44.1	1.4	---	---	---	---	---	---	3.9	---
F3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Unid.	---	---	---	---	---	---	---	---	---	---	---	7.4	---	---	---
Furcilia	---	---	---	---	23.1	79.1	39.6	---	---	---	---	7.4	---	23.1	6.9
No. 1000 m-3															
Mean	288.4	21.2	1.8	1.0	23.1	10.5	0.0	2.3	3.0	0.6	4.5	1.4	6.3	4.5	3.0
STD	771.6	55.4	4.4	4.9	41.6	20.3	0.0	4.8	10.2	2.0	4.1	4.3	11.9	6.0	4.1
Median	45.8	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.3	1.5	1.3

Survey	D01			D02				D03				D04			
Stage %	West	Eleph	South	West	Eleph	South	Joinvl	West	Eleph	South	Joinvl	West	Eleph	South	Joinvl
C1	37.6	58.4	17.8	3.2	42.2	50.3	---	100	63.4	78.8	100	31.6	14.2	37.5	17.8
C2	36.1	29.4	15.2	16.7	4.1	49.7	15.6	---	22.8	21.2	---	27.1	10.7	29.6	41.3
C3	18.0	10.7	67.0	70.0	23.5	---	29.5	---	---	---	---	40.2	8.0	14.9	13.5
Unid.	0.8	---	---	9.5	---	---	---	---	---	---	---	---	---	---	---
Calyptopis	92.5	98.6	100	99.3	69.8	100	45.1	100	86.2	100	100	98.9	32.9	82.0	72.6
F1	7.4	1.4	---	0.7	22.8	---	26.8	---	1.3	---	---	1.1	5.8	9.0	11.4
F2	0.1	---	---	---	7.4	---	12.1	---	12.5	---	---	---	29.3	4.7	13.4
F3	---	---	---	---	---	---	16.1	---	---	---	---	---	31.6	4.3	2.6
Unid.	---	---	---	---	---	---	---	---	---	---	---	---	0.4	---	---
Furcilia	7.5	1.4	---	0.7	30.2	---	54.9	---	13.8	---	---	1.1	67.1	18.0	27.4
No. 1000 m-3															
Mean	1363.2	45.5	3.1	86.8	32.1	2.6	18.8	0.1	3.9	1.8	3.1	46.1	105.0	41.4	63.0
STD	4071.1	113.1	6.3	245.5	90.6	7.0	24.7	0.4	8.3	5.9	5.1	122.0	478.0	49.1	66.4
Median	27.3	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	8.9	12.2	24.4	32.5

Table 4.3 (Contd.)

(B) Subareas (Contd.)

Survey	A05				A06				A07				A08			
Stage %	West	Eleph	South	Joinvl	West	Eleph	South	Joinvl	West	Eleph	South	Joinvl	West	Eleph	South	Joinvl
C1	84.3	90.8	64.2	78.6	94.2	99.9	94.7	99.9	100	100	99.0	97.3	80.1	99.6	66.1	38.2
C2	---	6.6	22.2	10.3	3.4	0.1	3.9	0.1	---	---	1.0	1.6	16.7	0.4	32.9	52.0
C3	---	0.2	8.0	11.0	---	---	---	---	---	---	---	1.1	0.0	---	0.5	7.5
Unid.	3.7	1.4	4.2	---	---	---	---	---	---	---	---	---	---	---	0.5	1.8
Calyptopis	88.0	100	98.6	100	97.6	100	98.6	100	100	100	100	100	96.8	100	100	99.5
F1	12.0	---	1.4	---	1.8	---	1.4	---	---	---	---	---	3.2	---	---	0.5
F2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
F3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Unid.	---	---	---	---	0.6	---	---	---	---	---	---	---	---	---	---	---
Furcilia	12.0	---	1.4	---	2.4	---	1.4	---	---	---	---	---	3.2	---	---	0.5
No. 1000 m-3																
Mean	1.8	14.2	17.0	19.9	5.3	1305.4	10.5	168.2	1.2	14.2	2.3	20.4	2.2	30.1	38.0	100.3
STD	5.3	50.3	51.2	26.1	14.2	3292.2	34.1	356.7	2.9	44.2	3.0	21.6	4.2	58.5	45.1	115.2
Med	0.0	0.7	0.6	8.9	0.0	12.1	0.0	9.1	0.0	1.5	1.2	8.9	0.0	6.3	16.8	34.5

Survey	D05				D06				D07				D08			
Stage %	West	Eleph	South	Joinvl									Eleph	South	Trans	SOI
C1	100	22.2	2.2	0.3	---	---	---	---	---	---	---	---	99.6	81.9	95.6	92.5
C2	---	45.0	15.6	86.0	---	---	---	---	---	---	---	---	0.4	15.2	4.4	7.5
C3	---	18.1	21.7	8.7	---	---	---	---	---	---	---	---	---	2.4	---	---
Unid.	---	4.5	---	---	---	---	---	---	---	---	---	---	---	0.4	---	---
Calyptopis	100	89.9	39.5	95.0	---	---	---	---	---	---	---	---	100	100	100	100.0
F1	---	9.9	46.3	3.5	---	---	---	---	---	---	---	---	---	---	---	---
F2	---	---	13.9	1.1	---	---	---	---	---	---	---	---	---	---	---	---
F3	---	---	---	0.4	---	---	---	---	---	---	---	---	---	---	---	---
Unid.	---	0.3	0.3	---	---	---	---	---	---	---	---	---	---	---	---	---
Furcilia	---	10.1	60.5	5.0	---	---	---	---	---	---	---	---	---	---	---	---
No. 1000 m-3																
Mean	0.5	125.3	127.9	652.5	---	---	---	---	---	---	---	---	115.9	50.7	205.3	2.0
STD	2.5	623.4	329.2	972.0	---	---	---	---	---	---	---	---	470.9	76.5	395.2	8.2
Med	0.0	2.9	0.3	21.3	---	---	---	---	---	---	---	---	4.4	12.6	8.1	0.0

Table 4.4. Composition and abundance of zooplankton assemblages sampled during (A) Survey A and (B) Survey D and the South Orkney Island survey. F(%) is frequency of occurrence in samples. R is rank and N(%) is percent of total mean abundance represented by each taxon. L and J denote larval and juvenile stages.

(A) Survey A — South Shetland Island Area

Taxon	F(%)	R	N(%)	Mean	STD	Median	Maximum
Copepods	100.0	1	61.8	752.6	770.1	571.9	4987.0
Other copepods (unid.)	98.8		20.6	250.8	182.7	187.4	747.7
Calanoides acutus	98.8		10.0	121.4	120.0	75.2	517.5
Pareuchaeta sp.	90.7		7.1	86.0	143.2	30.2	967.2
Rhincalanus gigas	84.9		1.3	15.3	20.3	7.8	123.3
Calanus propinquus	83.7		0.9	10.7	14.3	5.6	81.5
Metridia gerlachei	76.7		21.5	261.2	660.6	12.2	4434.6
Haloptilus ocellatus	32.6		0.1	1.8	4.0	0.0	25.7
Heterorhabdus sp.	25.6		0.1	0.9	2.3	0.0	16.3
Pareuchaeta antarctica	15.1		0.0	0.4	3.0	0.0	28.3
Pleuromama robusta	5.8		0.2	2.3	11.7	0.0	74.7
Copepodites	2.3		0.1	1.5	14.1	0.0	131.3
Candacia spp.	2.3		0.0	0.0	0.1	0.0	0.4
Thysanoessa macrura	97.7	2	19.2	233.5	264.1	140.0	1135.7
Chaetognaths	96.5	5	2.5	30.8	39.2	14.8	196.6
Primno macropa	93.0	6	0.8	9.9	9.5	7.2	48.1
Euphausia superba	91.9	3	6.6	80.7	275.6	5.8	2292.0
Radiolaria	87.2	7	0.7	8.7	9.4	6.2	60.1
Spongiobranchaea australis	83.7		0.1	1.3	1.9	0.8	12.4
Tomopteris spp.	70.9		0.2	2.3	3.6	0.9	20.5
Euphausia superba (L)	67.4	4	2.7	33.0	64.4	6.2	383.7
Limacina helicina	62.8		0.3	3.9	8.1	0.6	40.9
Hyperiella dilatata	60.5		0.0	0.5	0.8	0.2	3.8
Lepidonotothen larseni (L)	58.1		0.2	1.9	4.8	0.3	33.4
Themisto gaudichaudii	57.0		0.2	2.3	5.1	0.3	33.4
Larval Fish (unid)	57.0		0.1	1.0	1.8	0.3	12.9
Ostracods	54.7	10	0.5	5.9	18.2	0.6	151.2
Salpa thompsoni	52.3		0.4	5.0	10.8	0.2	82.5
Limacina spp.	44.2	8	0.6	7.6	12.9	0.0	52.4
Clione limacina	41.9		0.0	0.4	0.8	0.0	5.1
Sipunculids	40.7		0.2	2.9	6.5	0.0	34.9
Thysanoessa macrura (L)	38.4	9	0.5	6.2	19.2	0.0	127.6
Euphausia frigida	38.4		0.5	5.8	14.9	0.0	79.8
Siphonophora unid.	38.4		0.2	2.8	8.1	0.0	62.0
Polychaetes (unid)	37.2		0.1	0.9	1.6	0.0	8.2
Lepidonotothen kempi (L)	36.0		0.1	0.7	2.0	0.0	14.4
Eggs, Unid.	34.9		0.4	4.4	19.0	0.0	151.3
Cyllopus magellanicus	32.6		0.0	0.4	1.0	0.0	5.9
Vibilia antarctica	32.6		0.0	0.3	1.1	0.0	9.0
Electrona spp. (L)	32.6		0.0	0.2	0.5	0.0	4.2
Hydromedusae (unid)	30.2		0.0	0.5	1.5	0.0	11.0
Rhynchonereelia bongraini	29.1		0.0	0.6	1.3	0.0	8.0
Diphyes antarctica	29.1		0.0	0.2	0.3	0.0	2.1
Barnacle larvae	27.9		0.3	3.2	8.6	0.0	44.6
Pegantha martgon	27.9		0.0	0.2	0.5	0.0	3.5
Euphausia spp. (L)	26.7		0.1	0.7	1.4	0.0	7.1
Acanthophyra pelagica	26.7		0.0	0.3	0.8	0.0	4.4
Euphausia crystallorophias	23.3		0.1	0.7	2.4	0.0	12.4
Isopods (unid)	23.3		0.0	0.5	1.2	0.0	7.6
Amphipods (unid)	20.9		0.0	0.5	1.6	0.0	10.6
Euphausia triacantha	16.3		0.1	0.8	2.7	0.0	18.1
Clio pyramidata spp.	16.3		0.0	0.1	0.2	0.0	0.9
Pelagobia longicirrata	15.1		0.0	0.1	0.5	0.0	3.8
Orchomene spp.	15.1		0.0	0.1	0.3	0.0	2.2
Cyllopus lucasii	15.1		0.0	0.1	0.2	0.0	1.5
Ihlea racovitzai	12.8		0.0	0.2	0.9	0.0	6.3
Ctenophora (unid)	12.8		0.0	0.0	0.1	0.0	0.6
Hyperiella macronyx	11.6		0.0	0.1	0.3	0.0	1.9
Larvaceans	10.5		0.0	0.3	1.4	0.0	10.9
Chionodraco rastrospinosus (L)	10.5		0.0	0.1	0.3	0.0	2.6

(A) Survey A (Contd.) — South Shetland Island Area

Taxon	F(%)	%	Mean	STD	Median	Maximum
Euphausia frigida (L)	9.3	0.0	0.3	1.6	0.0	13.5
Hyperiella spp.	9.3	0.0	0.2	0.9	0.0	7.1
Eusirus antarcticus	9.3	0.0	0.1	0.5	0.0	4.0
Beroe spp.	9.3	0.0	0.1	0.4	0.0	3.9
Cyllopus spp.	8.1	0.0	0.1	0.6	0.0	5.2
Clio pyramidata sulcata?	8.1	0.0	0.1	0.4	0.0	3.4
Orchomene rossi	8.1	0.0	0.1	0.3	0.0	2.9
Thyploscolex muelleri	7.0	0.0	0.1	0.3	0.0	1.9
Decapods (unid.)	7.0	0.0	0.0	0.2	0.0	2.0
Spongiobranchaea sp.	7.0	0.0	0.0	0.2	0.0	1.5
Beroe cucumis	7.0	0.0	0.0	0.2	0.0	1.5
Dimophyes arctica	7.0	0.0	0.0	0.1	0.0	0.9
Scina spp.	5.8	0.0	0.1	0.5	0.0	4.4
Mertensia spp.	5.8	0.0	0.1	0.6	0.0	5.9
Euphausia spp.	5.8	0.0	0.0	0.2	0.0	1.3
Schyphomedusae (unid)	5.8	0.0	0.0	0.1	0.0	0.4
Gastropods (unid)	4.7	0.0	0.1	0.4	0.0	3.2
Nototheniops nudifrons (L)	4.7	0.0	0.0	0.2	0.0	1.3
Mysids (unid)	4.7	0.0	0.0	0.2	0.0	1.6
Hippolytidae	4.7	0.0	0.0	0.2	0.0	1.3
Orchomene plebs	4.7	0.0	0.0	0.1	0.0	1.1
Notolepis coatsi (L)	4.7	0.0	0.0	0.1	0.0	0.3
Cumaceans	3.5	0.0	0.0	0.2	0.0	1.7
Electrona carlsbergi	3.5	0.0	0.0	0.1	0.0	0.9
Epimeriella macronyx	3.5	0.0	0.0	0.1	0.0	0.5
Electrona antarctica	3.5	0.0	0.0	0.1	0.0	0.5
Calycopsis borchgrevinki	3.5	0.0	0.0	0.0	0.0	0.3
Clio pyramidata antarctica	3.5	0.0	0.0	0.0	0.0	0.2
Gobionotothen gibberifrons (L)	2.3	0.0	0.0	0.1	0.0	0.7
Hyperiids (unid.)	2.3	0.0	0.0	0.1	0.0	0.5
Eusirus properdentatus	2.3	0.0	0.0	0.1	0.0	0.4
Vanadis antarctica	2.3	0.0	0.0	0.0	0.0	0.2
Cephalopods	2.3	0.0	0.0	0.0	0.0	0.2
Harpagifer antarcticus (L)	1.2	0.0	0.1	1.3	0.0	11.7
Euphausia crystallorophias(L)	1.2	0.0	0.1	0.5	0.0	5.1
Notolepis spp. (L)	1.2	0.0	0.0	0.1	0.0	0.8
Egg, Fish	1.2	0.0	0.0	0.1	0.0	0.8
Trematomus scotti (L)	1.2	0.0	0.0	0.1	0.0	0.8
Bathylagus sp. (L)	1.2	0.0	0.0	0.1	0.0	0.5
Parachaenichthys charcoti (L)	1.2	0.0	0.0	0.1	0.0	0.5
Lepidonotothen larseni (J)	1.2	0.0	0.0	0.0	0.0	0.4
Eusirus spp.	1.2	0.0	0.0	0.0	0.0	0.3
Gammarids (unid)	1.2	0.0	0.0	0.0	0.0	0.3
Russallia mirabilis	1.2	0.0	0.0	0.0	0.0	0.3
Gymnodraco acuticeps (L)	1.2	0.0	0.0	0.0	0.0	0.2
Callanira antarctica	1.2	0.0	0.0	0.0	0.0	0.2
Pseudochaenichthys georgianus (L)	1.2	0.0	0.0	0.0	0.0	0.2
Periphylla periphylla	1.2	0.0	0.0	0.0	0.0	0.2
Modeeria rotunda?	1.2	0.0	0.0	0.0	0.0	0.2
Bolinopsis sp.	1.2	0.0	0.0	0.0	0.0	0.2
Lopadorhynchinae (family)	1.2	0.0	0.0	0.0	0.0	0.2
Racovittzia glacialis	1.2	0.0	0.0	0.0	0.0	0.2
Hyperia macrocephala	1.2	0.0	0.0	0.0	0.0	0.2
Notothenia neglecta	1.2	0.0	0.0	0.0	0.0	0.2
Hyperiella antarctica	1.2	0.0	0.0	0.0	0.0	0.0
Gerlachea australis (L)	1.2	0.0	0.0	0.0	0.0	0.0
Notothenia coriiceps	1.2	0.0	0.0	0.0	0.0	0.0
Cryodraco antarctica (J)	1.2	0.0	0.0	0.0	0.0	0.0
Total		100	1217.1	953.0	894.1	5449.3
No. Taxa	105		3.2	7.3	21.4	

Table 4.4 (Contd.)

(B) Survey D — South Orkney and South Shetland Island Areas

	South Orkney Island Area N=37						South Shetland Island Area N=65					
Taxon	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median
Copepods	100.0	1	68.9	1282.3	971.5	881.6	100.0	1	61.9	1347.2	1872.9	633.9
Calanoides acutus	100.0		20.3	378.2	459.1	253.2	100.0		7.4	160.8	165.9	115.4
Other copepods	97.3		12.5	231.8	158.5	192.9	98.5		14.4	312.9	245.6	263.0
Pareuchaeta spp.	97.3		3.7	68.9	79.7	40.5	96.9		2.7	58.0	70.4	29.7
Metridia gerlachei	91.9		30.4	566.6	754.9	241.1	93.8		33.4	727.0	1604.5	34.8
Rhincalanus gigas	89.2		0.7	13.0	12.9	10.8	90.8		2.2	47.2	45.4	35.8
Calanus propinquus	91.9		0.6	10.6	14.6	5.5	80.0		0.5	11.5	15.8	5.6
Haloptlus spp	21.6		0.1	1.1	2.5	0.0	49.2		0.3	6.6	13.4	0.0
Heterorhabdus sp.	24.3		0.2	3.1	11.5	0.0	41.5		0.6	13.2	43.8	0.0
Pareuchaeta antarctica	29.7		0.0	0.3	0.8	0.0	36.9		0.0	0.7	1.4	0.0
Haloptilus ocellatus	37.8		0.1	1.6	3.0	0.0	4.6		0.0	0.2	1.6	0.0
Pleuromama robusta	0.0		0.0	0.0	0.0	0.0	16.9		0.3	5.7	17.0	0.0
Copepodites	2.7		0.4	7.0	42.1	0.0	1.5		0.1	3.1	25.0	0.0
Eucalanus sp.	2.7		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Candacia spp.	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.1	0.0
Thysanoessa macrura	100.0	3	5.6	103.7	90.2	79.8	100.0	2	15.8	344.7	392.5	200.0
Chaetognaths	100.0	4	5.3	98.5	59.2	90.7	95.4	5	4.0	87.0	139.9	35.9
Primno macropa	100.0	9	0.7	13.0	10.4	8.9	78.5		0.3	5.5	7.6	2.9
Radiolaria	97.3	5	2.9	53.9	52.7	32.7	60.0		0.2	4.4	13.9	0.5
Acanthophyra pelagica	94.6		0.1	1.6	1.4	1.3	16.9		0.0	0.1	0.3	0.0
Siphonophores (unid.)	89.2	6	2.4	44.9	42.3	31.8	60.0	10	0.3	5.8	11.6	1.1
Euphausia superba	86.5	2	9.4	174.9	369.3	5.0	89.2	3	8.5	184.7	669.6	8.3
Thysanoessa macrura (L)	86.5	8	0.7	13.3	15.9	8.2	47.7		0.1	2.5	4.6	0.0
Fish (L) (unid.)	86.5		0.2	2.8	2.9	1.4	32.3		0.0	0.4	0.8	0.0
Diphyes antarctica	70.3		0.0	0.7	0.9	0.3	16.9		0.0	0.1	0.2	0.0
Electrona spp. (L)	67.6		0.1	1.2	1.4	0.5	58.5		0.0	0.6	0.9	0.2
Tomopteris spp.	64.9		0.1	2.0	3.0	0.6	55.4		0.1	1.5	3.6	0.3
Sipunculids	64.9		0.0	0.7	1.2	0.3	21.5		0.0	0.2	0.6	0.0
Ostracods	62.2	7	1.1	20.9	33.3	2.5	58.5	8	0.8	17.2	45.4	1.6
Spongiobranchaea australis	62.2		0.0	0.5	0.8	0.3	64.6		0.0	0.7	1.3	0.2
Clione limacina	59.5		0.0	0.6	0.8	0.3	10.8		0.0	0.1	0.3	0.0
Hyperiella dilatata	56.8		0.0	0.7	1.3	0.3	32.3		0.0	0.3	1.0	0.0
Orchomene spp.	54.1		0.3	4.8	8.4	0.3	6.2		0.0	0.0	0.1	0.0
Themisto gaudichaudii	51.4		0.1	1.1	2.1	0.2	96.9	9	0.4	8.0	10.8	4.8
Rhynchonereelia bongraini	43.2		0.1	1.6	2.4	0.0	16.9		0.0	0.5	1.9	0.0
Isopods (unid.)	43.2		0.1	1.4	1.9	0.0	20.0		0.0	0.4	1.2	0.0
Euphausia frigida	40.5		0.3	6.4	17.8	0.0	63.1	6	1.8	38.8	85.1	1.1
Polychaetes (unid.)	40.5		0.0	0.9	2.2	0.0	12.3		0.0	0.2	0.7	0.0
Eusirus antarcticus	37.8		0.0	0.3	0.6	0.0	1.5		0.0	0.0	0.1	0.0
Eggs (unid.)	35.1		0.1	2.6	5.3	0.0	27.7		0.1	1.5	6.0	0.0
Lepidonotothen kempi (L)	35.1		0.1	1.1	3.3	0.0	66.2		0.0	0.5	0.6	0.3
Hyperiella spp.	35.1		0.0	0.9	1.3	0.0	15.4		0.0	0.2	0.8	0.0
Larvaceans	32.4		0.3	4.8	10.4	0.0	27.7		0.1	1.3	2.9	0.0
Notolepis coatsi (L)	29.7		0.0	0.3	0.6	0.0	24.6		0.0	0.2	0.5	0.0
Lepidonotothen larseni (L)	29.7		0.0	0.3	0.6	0.0	27.7		0.0	0.4	1.3	0.0
Limacina helicina	29.7		0.0	0.2	0.3	0.0	12.3		0.0	0.2	0.7	0.0
Limacina spp.	27.0		0.1	1.2	2.5	0.0	21.5		0.0	0.8	2.0	0.0
Euphausia spp. (L)	27.0		0.0	0.7	2.1	0.0	4.6		0.0	0.5	2.5	0.0
Decapods (L) (unid.)	24.3		0.0	0.1	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Euphausia frigida (L)	21.6		0.0	0.8	1.8	0.0	7.7		0.0	0.4	2.2	0.0
Cephalopods	21.6		0.0	0.1	0.4	0.0	4.6		0.0	0.0	0.0	0.0
Mysids (unid.)	18.9	10	0.4	7.1	31.7	0.0	1.5		0.0	0.0	0.0	0.0
Salpa thompsoni	16.2		0.2	3.5	20.4	0.0	47.7	7	0.9	19.1	50.6	0.0
Euphausia superba (L)	16.2		0.1	2.0	8.2	0.0	70.8	4	4.4	94.8	391.1	4.9
Hydromedusae (unid.)	16.2		0.0	0.3	0.8	0.0	16.9		0.0	0.2	0.8	0.0
Notolepis annulata (L)	16.2		0.0	0.1	0.1	0.0	3.1		0.0	0.0	0.0	0.0
Hyperiella macronyx	16.2		0.0	0.0	0.1	0.0	6.2		0.0	0.0	0.1	0.0
Clio pyramidata sulcata?	13.5		0.0	0.1	0.6	0.0	0.0		0.0	0.0	0.0	0.0
Calycopsis borchgrevinki	13.5		0.0	0.1	0.3	0.0	16.9		0.0	0.1	0.1	0.0
Clio pyramidata spp?	10.8		0.0	0.4	2.3	0.0	0.0		0.0	0.0	0.0	0.0
Amphipods (unid.)	10.8		0.0	0.3	0.9	0.0	23.1		0.1	1.2	3.0	0.0

(B) Survey D — South Orkney and South Shetland Island Areas

	South Orkney Island Area N=37						South Shetland Island Area N=65					
Taxon	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median
Fish eggs	10.8		0.0	0.2	0.8	0.0	3.1		0.0	0.0	0.3	0.0
Euphausia spp.	10.8		0.0	0.1	0.6	0.0	9.2		0.0	1.0	6.5	0.0
Epimeriella macronyx	10.8		0.0	0.1	0.4	0.0	0.0		0.0	0.0	0.0	0.0
Cyllopus lucasii	10.8		0.0	0.0	0.1	0.0	15.4		0.0	0.1	0.3	0.0
Orchomene rossi	8.1		0.0	0.3	1.7	0.0	3.1		0.0	0.0	0.1	0.0
Spongiobranchaea sp.	8.1		0.0	0.2	0.6	0.0	4.6		0.0	0.1	0.4	0.0
Thyploscolex muelleri	8.1		0.0	0.1	0.4	0.0	3.1		0.0	0.0	0.0	0.0
Pleuragramma antarctic	8.1		0.0	0.1	0.2	0.0	0.0		0.0	0.0	0.0	0.0
Gastropods (unid.)	8.1		0.0	0.0	0.2	0.0	3.1		0.0	0.0	0.1	0.0
Electrona antarctica	8.1		0.0	0.0	0.2	0.0	16.9		0.0	0.1	0.2	0.0
Dimophyes arctica	8.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Pelagobia longicirrata	8.1		0.0	0.0	0.1	0.0	3.1		0.0	0.0	0.1	0.0
Notolepis spp. (L)	5.4		0.0	0.0	0.2	0.0	0.0		0.0	0.0	0.0	0.0
Vibilia antarctica	5.4		0.0	0.0	0.1	0.0	29.2		0.0	0.5	1.4	0.0
Ctenophora (unid.)	5.4		0.0	0.0	0.1	0.0	7.7		0.0	0.0	0.1	0.0
Beroe spp.	5.4		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Russallia mirabilis	5.4		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Chionodraco rastrospino	5.4		0.0	0.0	0.1	0.0	1.5		0.0	0.0	0.0	0.0
Pleuragramma antarctic	5.4		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Schyphomedusae (unid	2.7		0.0	0.6	3.5	0.0	6.2		0.0	0.0	0.1	0.0
Clio pyramidata antarcti	2.7		0.0	0.1	0.4	0.0	0.0		0.0	0.0	0.0	0.0
Eusirus spp.	2.7		0.0	0.0	0.2	0.0	1.5		0.0	0.0	0.1	0.0
Notothenia squamifrons	2.7		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Vanadis antarctica	2.7		0.0	0.0	0.1	0.0	7.7		0.0	0.0	0.1	0.0
Ihlea racovitzai	2.7		0.0	0.0	0.0	0.0	6.2		0.0	0.1	0.7	0.0
Decapods (L)	2.7		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hyperiids (unid.)	2.7		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Trematomus eulepidotu	2.7		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Tunicate (unid.)	2.7		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Pandea rubra	2.7		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Beroe cucumis	2.7		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Cyllopus magellanicus	2.7		0.0	0.0	0.0	0.0	40.0		0.0	1.0	2.1	0.0
Hyperiella antarctica	2.7		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Krefftichthys andersson	2.7		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Euphausia triacantha	0.0		0.0	0.0	0.0	0.0	23.1		0.0	0.9	2.2	0.0
Pegantha martgon	0.0		0.0	0.0	0.0	0.0	21.5		0.0	0.1	0.3	0.0
Euphausia crystalloroph	0.0		0.0	0.0	0.0	0.0	13.8		0.0	0.2	1.0	0.0
Barnacle (L)	0.0		0.0	0.0	0.0	0.0	13.8		0.0	0.2	0.6	0.0
Gymnoscopelus braueri	0.0		0.0	0.0	0.0	0.0	12.3		0.0	0.1	0.2	0.0
Scina spp.	0.0		0.0	0.0	0.0	0.0	4.6		0.0	0.1	0.9	0.0
Cumaceans	0.0		0.0	0.0	0.0	0.0	4.6		0.0	0.0	0.1	0.0
Cyllopus spp.	0.0		0.0	0.0	0.0	0.0	4.6		0.0	0.0	0.1	0.0
Oediceroides calmani?	0.0		0.0	0.0	0.0	0.0	3.1		0.0	0.0	0.1	0.0
Mertensia spp.	0.0		0.0	0.0	0.0	0.0	3.1		0.0	0.0	0.1	0.0
Callanira antarctica	0.0		0.0	0.0	0.0	0.0	3.1		0.0	0.0	0.1	0.0
Eusirus properdentatus	0.0		0.0	0.0	0.0	0.0	3.1		0.0	0.0	0.1	0.0
Gymnoscopelus bolini	0.0		0.0	0.0	0.0	0.0	3.1		0.0	0.0	0.1	0.0
Lepidonotothen larseni (	0.0		0.0	0.0	0.0	0.0	3.1		0.0	0.0	0.1	0.0
Orchomene plebs	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.1	0.0
Paradiplospinus antarcti	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Protomyctophum spp.	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Bathylagus sp. (L)	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Protomyctophum bolini	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Periphylla periphylla	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Cyphocaris richardi	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Gymnoscopelus nichols	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Gammarids (unid.)	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Eusirus perdentatus	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Nototheniid (L) (unid.)	0.0		0.0	0.0	0.0	0.0	1.5		0.0	0.0	0.0	0.0
Total				####	###	1623.3				####	###	1090.2
Taxa	93			25.2	4.9	27.0	89			4.8	1.4	4.9

Table 4.5. Composition and abundance of zooplankton assemblages sampled in four subareas areas during (A) January Survey A and in five areas during (B) February-March Survey D, 2008. F(%) is frequency of occurrence in samples. R is rank and N(%) is proportion of total mean abundance represented by each taxon. (L) and (J) denote larval and juvenile stages.

(A) January Survey A

	West Area (N=22)						Elephant Island Area (N=34)						Joinville Island Area (N=10)						South Area (N=20)					
Taxon	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median
Copepods	100.0	1	53.0	510.7	430.4	323.5	100.0	1	66.0	828.4	959.0	585.3	100.0	1	52.7	550.1	364.4	531.6	100.0	1	65.3	991.1	751.5	675.2
Calanus propinquus	100.0		1.5	14.6	19.4	6.0	91.2		0.9	11.1	11.9	7.4	60.0		0.8	8.4	14.4	1.3	65.0		0.5	6.8	8.9	3.9
Other copepods	95.5		19.8	190.8	163.9	142.2	100.0		24.0	301.3	192.9	246.1	100.0		21.8	227.4	192.3	188.4	100.0		16.0	242.9	153.5	214.3
Calanoides acutus	95.5		10.0	96.0	107.3	61.1	100.0		7.9	99.5	106.0	56.6	100.0		14.0	146.4	138.7	122.2	100.0		11.5	174.2	126.2	168.3
Pareuchaeta spp.	86.4		10.8	104.3	206.1	22.2	85.3		4.0	50.8	89.9	16.5	100.0		8.4	87.7	87.9	62.8	100.0		8.2	125.0	141.0	68.2
Rhincalanus gigas	86.4		1.9	18.7	26.6	10.1	88.2		1.2	14.9	16.7	10.4	70.0		1.0	10.7	16.9	2.7	85.0		1.0	14.4	18.7	7.0
Metridia gerlachei	81.8		7.8	75.5	115.8	19.2	73.5		27.3	342.4	863.2	52.4	70.0		6.6	68.4	198.7	1.3	80.0		27.9	423.8	693.6	90.1
Haloptilus ocellatus	40.9		0.3	2.6	4.8	0.0	26.5		0.1	1.0	2.0	0.0	30.0		0.1	0.8	1.3	0.0	35.0		0.2	2.8	5.8	0.0
Heterorhabdus sp.	27.3		0.1	1.2	3.4	0.0	32.4		0.1	0.9	1.5	0.0	20.0		0.0	0.3	0.7	0.0	15.0		0.1	0.9	2.3	0.0
Pleuromama robusta	9.1		0.1	0.6	1.9	0.0	8.8		0.4	5.6	18.2	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Pareuchaeta antarctica	9.1		0.0	0.0	0.2	0.0	11.8		0.1	0.9	4.8	0.0	20.0		0.0	0.1	0.2	0.0	25.0		0.0	0.2	0.4	0.0
Copepodites	4.5		0.6	6.0	27.4	0.0	2.9		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Candacia spp.	4.5		0.0	0.0	0.1	0.0	2.9		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Primno macropa	100.0	5	1.2	11.1	10.1	7.8	91.2	6	0.7	8.7	9.5	6.1	80.0		0.5	5.2	6.7	2.3	95.0	10	0.8	12.7	8.8	10.6
Thysanoessa macrura	95.5	2	31.8	306.6	329.3	227.4	100.0	2	15.9	199.2	191.7	130.8	90.0	4	9.5	98.6	170.0	5.4	100.0	2	18.4	278.9	290.7	186.7
Chaetognaths	95.5	3	4.2	40.7	48.8	26.9	94.1	5	1.6	20.4	25.7	11.2	100.0	7	1.6	16.4	13.3	13.0	100.0	3	3.0	45.0	46.8	16.9
Euphausia superba	86.4	4	3.3	31.5	60.1	5.1	97.1	3	9.6	119.9	400.1	14.3	80.0	2	15.9	165.9	251.6	1.5	95.0	5	1.7	25.7	83.7	1.0
Spongiobranchaea australis	86.4		0.1	1.3	1.8	0.9	85.3		0.1	1.3	1.3	0.9	80.0		0.1	0.9	0.9	0.8	80.0		0.1	1.5	2.9	0.3
Radiolaria	81.8	8	0.8	7.7	7.2	5.6	91.2	8	0.6	7.0	6.5	5.4	100.0	8	1.3	13.8	9.9	12.4	80.0		0.7	10.3	13.6	5.7
Themisto gaudichaudii	81.8	10	0.6	6.2	8.7	2.4	76.5		0.1	1.5	1.5	1.4	20.0		0.0	0.0	0.1	0.0	15.0		0.0	0.6	1.8	0.0
Tomopteris spp.	77.3		0.2	1.8	1.8	1.2	61.8		0.1	1.1	2.8	0.2	60.0		0.3	2.6	3.4	0.3	85.0		0.3	4.5	5.1	2.9
Limacina helicina	72.7	9	0.7	7.2	10.6	3.1	44.1	10	0.3	3.6	8.6	0.0	70.0		0.1	1.5	1.7	0.7	80.0		0.1	2.2	3.2	0.6
Salpa thompsoni	68.2	6	1.0	9.7	17.1	6.0	76.5	9	0.4	5.2	7.2	2.6	0.0		0.0	0.0	0.0	0.0	20.0		0.1	1.9	7.0	0.0
Ostracods	59.1		0.4	3.6	6.0	1.3	52.9		0.2	2.8	4.5	0.5	50.0		0.4	4.6	8.4	0.4	55.0	8	0.9	14.3	35.0	0.4
Fish (L) (unid.)	59.1		0.1	0.8	0.9	0.7	58.8		0.1	1.5	2.5	0.4	50.0		0.1	0.7	1.4	0.1	55.0		0.0	0.4	0.7	0.2
Vibilia antarctica	54.5		0.0	0.4	0.5	0.2	41.2		0.0	0.3	0.6	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.5	2.0	0.0
Hyperiella dilatata	50.0		0.0	0.4	0.5	0.1	58.8		0.0	0.6	0.9	0.2	60.0		0.0	0.3	0.3	0.2	75.0		0.0	0.7	1.0	0.3
Cyllopus magellanicus	40.9		0.1	0.6	1.4	0.0	47.1		0.0	0.4	0.6	0.0	0.0		0.0	0.0	0.0	0.0	15.0		0.0	0.4	1.3	0.0
Euphausia superba (L)	36.4		0.2	2.2	4.2	0.0	70.6	4	2.4	30.1	58.5	6.3	90.0	3	9.6	100.3	115.2	34.5	85.0	4	2.5	38.0	45.1	16.8
Amphipods (unid)	36.4		0.1	0.9	2.2	0.0	14.7		0.0	0.4	1.5	0.0	30.0		0.0	0.4	0.6	0.0	10.0		0.0	0.2	0.9	0.0
Rhynchonereelia bongraini	36.4		0.1	0.7	1.2	0.0	20.6		0.0	0.2	0.5	0.0	30.0		0.1	0.8	1.6	0.0	35.0		0.1	0.9	1.9	0.0
Electrona spp. (L)	36.4		0.0	0.1	0.3	0.0	32.4		0.0	0.1	0.2	0.0	20.0		0.0	0.1	0.3	0.0	35.0		0.0	0.4	1.0	0.0
Thysanoessa macrura (L)	31.8		0.2	1.7	3.8	0.0	20.6		0.1	1.4	5.5	0.0	50.0		0.6	6.0	8.5	0.7	70.0	7	1.3	19.3	35.2	6.0
Lepidonotothen larseni (L)	31.8		0.1	1.4	3.8	0.0	47.1		0.1	1.6	4.2	0.0	100.0		0.2	2.1	1.4	2.4	85.0		0.2	3.0	7.1	1.2
Polychaetes (unid.)	31.8		0.1	0.9	1.6	0.0	35.3		0.1	0.7	1.2	0.0	40.0		0.1	0.8	1.5	0.0	45.0		0.1	1.1	2.0	0.0
Clione limacina	31.8		0.1	0.5	1.1	0.0	32.4		0.0	0.3	0.6	0.0	70.0		0.0	0.4	0.3	0.5	55.0		0.0	0.5	0.6	0.2
Hydromedusae (unid.)	31.8		0.0	0.1	0.2	0.0	11.8		0.0	0.0	0.1	0.0	50.0		0.2	1.7	3.2	0.1	50.0		0.1	1.2	1.5	0.2
Euphausia frigida	27.3	7	0.8	7.8	16.7	0.0	50.0	7	0.7	8.7	18.6	0.1	50.0		0.1	1.4	3.3	0.1	25.0		0.1	0.8	2.2	0.0
Lepidonotothen kempi (L)	27.3		0.1	1.0	3.1	0.0	38.2		0.0	0.4	0.9	0.0	40.0		0.1	0.6	0.8	0.0	40.0		0.1	1.1	2.1	0.0
Pegantha martgon	27.3		0.0	0.3	0.7	0.0	47.1		0.0	0.3	0.6	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.1	0.0
Siphonophores (unid.)	22.7		0.1	1.0	2.5	0.0	29.4		0.1	1.2	2.8	0.0	80.0		0.3	3.2	3.2	2.4	50.0		0.5	7.3	15.0	0.2
Euphausia crystallorophias	22.7		0.1	0.6	2.2	0.0	8.8		0.0	0.1	0.3	0.0	20.0		0.1	1.3	3.4	0.0	50.0		0.1	1.5	3.4	0.1
Euphausia spp. (L)	22.7		0.0	0.4	0.8	0.0	14.7		0.0	0.2	0.6	0.0	60.0		0.1	1.5	1.6	1.4	35.0		0.1	1.3	2.1	0.0
Cyllopus lucasii	22.7		0.0	0.1	0.2	0.0	17.6		0.0	0.1	0.3	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.1	0.2	0.0
Clio pyramidata spp?	22.7		0.0	0.1	0.1	0.0	17.6		0.0	0.1	0.2	0.0	30.0		0.0	0.2	0.3	0.0	0.0		0.0	0.0	0.0	0.0
Limacina spp.	18.2		0.0	0.4	1.1	0.0	26.5		0.1	1.5	4.8	0.0	80.0	5	1.7	17.3	12.8	18.7	85.0	6	1.4	21.0	15.6	20.8
Cyllopus spp.	18.2		0.0	0.4	1.2	0.0	5.9		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.2	0.0
Acanthophyra pelagica (L)	18.2		0.0	0.4	1.0	0.0	23.5		0.0	0.3	0.7	0.0	40.0		0.1	0.6	0.9	0.0	35.0		0.0	0.1	0.2	0.0
Hyperiella spp.	18.2		0.0	0.2	0.5	0.0	2.9		0.0	0.0	0.3	0.0	0.0		0.0	0.0	0.0	0.0	15.0		0.0	0.5	1.6	0.0
Spongiobranchaea sp.	18.2		0.0	0.1	0.4	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.1	0.0
Euphausia triacantha	13.6		0.0	0.3	1.1	0.0	20.6		0.1	1.5	4.0	0.0	0.0		0.0	0.0	0.0	0.0	20.0		0.0	0.3	0.8	0.0
Eggs (unid.)	13.6		0.0	0.3	0.7	0.0	35.3		0.0	0.6	1.2	0.0	60.0	10	0.8	8.8	18.0	0.8	45.0	9	0.9	13.3	35.5	0.0
Barnacle (L)	9.1		0.0	0.1	0.3	0.0	17.6		0.0	0.2	0.7	0.0	70.0	6	1.6	17.0	15.5	17.3	45.0		0.3	4.7	8.5	0.0
Euphausia spp.	9.1		0.0	0.1	0.2	0.0	5.9		0.0	0.1	0.2	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.0	0.0
Clio pyramidata sulcata?	9.1		0.0	0.1	0.2	0.0	5.9		0.0	0.1	0.6	0.0	10.0		0.0	0.0	0.1	0.0	10.0		0.0	0.0	0.1	0.0
Diphyes antarctica	9.1		0.0	0.0	0.1	0.0	23.5		0.0	0.1	0.2	0.0	60.0		0.0	0.5	0.6	0.2	45.0		0.0	0.2	0.4	0.0
Vanadis antarctica	9.1		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Euphausia frigida (L)	4.5		0.1	0.6	2.8	0.0	17.6		0.0	0.4	0.9	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.2	0.0
Ihlea racovitzai	4.5		0.0	0.2	1.0	0.0	11.8		0.0	0.2	0.6	0.0	0.0		0.0	0.0	0.0	0.0	30.0		0.0	0.5	1.4	0.0
Mysids (unid.)	4.5		0.0	0.1	0.3	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.0	0.0	10.0		0.0	0.1	0.2	0.0
Isopods (unid.)	4.5		0.0	0.1	0.3	0.0	11.8		0.0	0.2	0.5	0.0	60.0		0.1	1.4	2.2	0.7	45.0		0.1	1.0	1.4	0.0
Gastropods (unid.)	4.5		0.0	0.0	0.2	0.0	2.9		0.0	0.1	0.5	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.1	0.2	0.0
Orchomene spp.	4.5		0.0	0.0	0.2	0.0	0.0		0.0	0.0	0.0	0.0	50.0		0.0	0.4	0.7	0.1	35.0		0.0	0.2	0.3	0.0
Trematomus scotti (L)	4.5		0.0	0.0	0.2	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Cumaceans	4.5		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.1	0.4	0.0
Sipunculids	4.5		0.0	0.0	0.1	0.0	26.5		0.0	0.4	1.3	0.0	90.0	9	1.0	10.7	10.8	4.8	80.0		0.4	6.2	7.7	3.7
Chionodraco rastrospinosus (L)	4.5		0.0	0.0	0.1	0.0	5.9		0.0	0.1	0.4	0.0	20.0		0.0	0.0	0.1	0.0	20.0		0.0	0.1	0.2	0.0
Decapods (L) (unid.)	4.5		0.0	0.0	0.1	0.0	2.9		0.0	0.1	0.3	0.0	0.0		0.0	0.0	0.0	0.0	20.0		0.0	0.1	0.1	0.0
Gammarids (unid.)	4.5		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hyperiids (unid.)	4.5		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.1	0.0
Modeeria rotunda?	4.5		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Ctenophore (unid.)	4.5		0.0	0.0	0.0	0.0	11.8		0.0	0.0	0.1	0.0	20.0		0.0	0.0	0.1	0.0	20.0		0.0	0.1	0.2	0.0
Electrona carlsbergi	4.5		0.0	0.0	0.0	0.0	5.9		0.0	0.0	0.2	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Bolinopsis sp.	4.5		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Notolepis coatsi (L)	4.5		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.1	0.0
Beroe spp.	4.5		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.0	0.0	30.0		0.0	0.5	1.2	0.0	15.0		0.0	0.0	0.1	0.0
Eusirus antarcticus	0.0		0.0	0.0	0.0	0.0	14.7		0.0	0.1	0.4	0.0	10.0		0.0	0.0	0.1	0.0	10.0		0.0	0.2	0.9	0.0
Scina spp.	0.0		0.0	0.0	0.0	0.0	11.8		0.0	0.2	0.8	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.1	0.4	0.0
Pelagobia longicirrata	0.0		0.0	0.0	0.0	0.0	11.8		0.0	0.0	0.1	0.0	40.0		0.0	0.5	0.9	0.0	25.0		0.0	0.3	0.8	0.0
Larvaceans	0.0		0.0	0.0	0.0	0.0	8.8		0.0	0.3	1.0	0.0	10.0		0.1	1.1	3.3	0.0	25.0		0.0	0.4	1.1	0.0
Electrona antarctica	0.0		0.0	0.0	0.0	0.0	8.8		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Hyperiella macronyx	0.0		0.0	0.0	0.0	0.0	5.9		0.0	0.0	0.1	0.0	30.0		0.0	0.2	0.4	0.0	25.0		0.0	0.2	0.4	0.0
Clio pyramidata antarctica?	0.0		0.0	0.0	0.0	0.0	5.9		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.0	0.0
Schyphomedusae (unid.)	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.1	0.0	15.0		0.0	0.0	0.1	0.0
Russallia mirabilis	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Periphylla periphylla	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Orchomene rossi	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.1	0.5	0.0	30.0		0.0	0.2	0.3	0.0	15.0		0.0	0.0	0.1	0.0

Table 4.5 (contd.)

(A) January Survey A (Contd.)

	West Area (N=22)						Elephant Island Area (N=34)						Joinville Island Area (N=10)						South Area (N=20)					
Taxon	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median
Mertensia spp.	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.0	0.0	20.0		0.1	0.6	1.7	0.0	10.0		0.0	0.0	0.1	0.0
Gymnodraco acuticeps (L)	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Gerlachea australis (L)	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Eusirus spp.	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Calycopsis borchgrevinki	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.1	0.0	5.0		0.0	0.0	0.0	0.0
Callanira antarctica	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Beroe cucumis	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.1	0.0	40.0		0.0	0.2	0.5	0.0	5.0		0.0	0.0	0.1	0.0
Bathylagus sp. (L)	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Epimeriella macronyx	0.0		0.0	0.0	0.0	0.0	2.9		0.0	0.0	0.1	0.0	10.0		0.0	0.0	0.1	0.0	5.0		0.0	0.0	0.1	0.0
Thyploscolex muelleri	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.1	0.3	0.0	25.0		0.0	0.3	0.6	0.0
Racovittzia glacialis	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.0	0.0
Pseudochaenichthys georgianus	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.1	0.0
Parachaenichthys charcoti (L)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.1	0.0
Orchomene plebs	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	20.0		0.0	0.1	0.3	0.0
Nototheniops nudifrons (L)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	30.0		0.0	0.3	0.5	0.0	5.0		0.0	0.0	0.1	0.0
Notothenia neglecta	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Notothenia coriiceps	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Notolepis spp. (L)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.1	0.3	0.0	0.0		0.0	0.0	0.0	0.0
Lopadorhynchinae (family)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.0	0.0
Lepidonotothen larseni (J)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.1	0.0
Hyperiella antarctica	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.0	0.0
Hyperia macrocephala	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0
Hippolytidae	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	20.0		0.0	0.2	0.4	0.0	10.0		0.0	0.0	0.1	0.0
Harpagifer antarcticus (L)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.6	2.6	0.0
Gobionotothen gibberifrons (L)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	20.0		0.0	0.1	0.2	0.0	0.0		0.0	0.0	0.0	0.0
Eusirus properdentatus	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.1	0.0
Euphausia crystallorophias (L)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.5	1.5	0.0	0.0		0.0	0.0	0.0	0.0
Fish egg (unid.)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.2	0.0
Dimophyes arctica	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	20.0		0.0	0.0	0.1	0.0	20.0		0.0	0.1	0.2	0.0
Cryodraco antarctica (J)	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	5.0		0.0	0.0	0.0	0.0
Cephalopods	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	10.0		0.0	0.0	0.1	0.0	5.0		0.0	0.0	0.0	0.0
Total				963.7	562.8	818.1				1254.8	1189.7	884.8	0.0			1042.9	357.2	966.3	0.0			1518.8	952.7	1169.1
Taxa	65			4.8	1.9	4.5	74			5.1	1.7	5.1		63		6.2	0.8	6.4	85			7.0	2.9	6.6

(B) February-March Survey D

	South Orkney Islands North Shelf Area (N=14)						South Orkney Islands South Shelf Area (N=23)						Transit South Shelf Area (N=7)						South Shetland Islands Elephant Island Area (N=44)						South Shetland Islands South Area (N=21)					
Taxon	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median	F(%)	R	N(%)	Mean	STD	Median
Copepods	100.0	1	76.6	1355.2	1053.6	956.2	100.0	1	64.6	1237.9	915.1	775.4	100.0	1	65.4	1570.9	1063.1	1035.8	100.0	1	65.2	1428.0	2125.6	621.0	100.0	1	54.9	1177.8	1161.4	658.4
Calanoides acutus	100.0		23.6	418.5	310.5	341.4	100.0		18.4	353.6	528.0	218.0	100.0		34.2	822.4	664.3	591.9	100.0		7.5	163.6	147.5	114.3	100.0		7.2	155.1	198.9	116.7
Other copepods	92.9		14.6	258.2	186.5	206.0	100.0		11.3	215.8	136.3	184.5	100.0		6.8	163.6	88.2	102.1	100.0		14.7	321.6	264.8	262.5	95.2		13.7	294.8	198.0	271.4
Pareuchaeta spp.	100.0		3.8	67.8	80.1	34.4	95.7		3.6	69.6	79.5	45.0	85.7		1.4	33.8	41.0	11.2	95.5		2.6	56.5	69.4	27.5	100.0		2.9	61.3	72.5	29.7
Metridia gerlachei	100.0		31.3	554.3	773.1	197.1	87.0		29.9	574.1	743.5	241.1	100.0		21.1	507.4	762.9	14.0	95.5		35.7	782.3	1819.1	30.6	90.5		28.5	611.2	1007.9	55.3
Rhincalanus gigas	92.9		1.0	17.0	17.9	11.4	87.0		0.5	10.5	7.6	9.9	100.0		1.2	28.5	21.0	17.8	95.5		2.7	58.3	47.7	40.3	81.0		1.1	23.8	28.6	8.5
Calanus propinquus	100.0		0.6	10.1	8.5	8.2	87.0		0.6	10.9	17.3	3.7	100.0		0.5	13.0	7.5	10.8	77.3		0.4	9.2	13.9	3.2	85.7		0.8	16.3	18.4	12.4
Haloptlus spp	7.1		0.0	0.2	0.5	0.0	30.4		0.1	1.7	3.0	0.0	28.6		0.0	1.2	2.3	0.0	56.8		0.4	8.4	15.5	1.5	33.3		0.1	2.8	5.3	0.0
Heterorhabdus sp.	28.6		0.4	7.1	17.9	0.0	21.7		0.0	0.7	1.4	0.0	0.0		0.0	0.0	0.0	0.0	47.7		0.9	18.9	52.3	0.0	28.6		0.1	1.3	3.3	0.0
Pareuchaeta antarctica	42.9		0.0	0.6	1.3	0.0	21.7		0.0	0.1	0.2	0.0	42.9		0.0	0.6	0.9	0.0	29.5		0.0	0.7	1.4	0.0	52.4		0.0	0.9	1.5	0.2
Haloptilus ocellatus	42.9		0.2	2.8	3.8	0.0	34.8		0.0	0.9	2.0	0.0	14.3		0.0	0.4	0.9	0.0	4.5		0.0	0.3	1.9	0.0	4.8		0.0	0.0	0.1	0.0
Pleuromama robusta	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	22.7		0.4	8.2	20.1	0.0	4.8		0.0	0.5	2.4	0.0
Copepodites	7.1		1.0	18.5	66.8	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	4.8		0.5	9.7	43.3	0.0
Eucalanus sp.	0.0		0.0	0.0	0.0	0.0	4.3		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
Candacia spp.	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	14.3		0.0	0.1	0.1	0.0	0.0		0.0	0.0	0.0	0.0	4.8		0.0	0.0	0.1	0.0
Chaetognaths	100.0	3	4.9	86.4	51.3	83.0	100.0	4	5.5	105.9	62.4	95.1	100.0	8	1.1	26.1	29.5	14.2	97.7	4	4.4	97.1	157.5	46.5	90.5	4	3.1	65.6	89.2	28.6
Thysanoessa macrura	100.0	4	4.4	77.2	46.2	77.0	100.0	3	6.3	119.9	105.3	87.7	100.0	3	10.3	247.9	194.7	217.5	100.0	2	15.3	336.1	363.3	207.1	100.0	3	16.9	362.8	447.0	184.6
Radiolaria	100.0	5	2.0	36.3	47.9	20.3	95.7	5	3.4	64.7	52.6	50.6	85.7	10	0.8	19.5	22.3	6.1	68.2	10	0.3	5.9	16.6	1.0	42.9		0.1	1.1	1.7	0.0
Primno macropa	100.0	7	1.1	18.6	6.9	18.7	100.0	10	0.5	9.6	10.6	6.5	100.0	9	0.6	14.3	24.6	4.4	77.3	9	0.3	6.9	8.7	4.1	81.0		0.1	2.6	2.3	1.9
Acanthophyra pelagica	100.0		0.1	1.5	1.1	1.1	91.3		0.1	1.6	1.6	1.3	71.4		0.0	0.7	0.9	0.2	15.9		0.0	0.1	0.3	0.0	19.0		0.0	0.1	0.2	0.0
Themisto gaudichaudii	92.9		0.1	2.6	2.8	1.5	26.1		0.0	0.2	0.3	0.0	42.9		0.1	3.1	6.1	0.0	100.0		0.3	5.7	5.0	4.7	90.5	8	0.6	12.9	16.6	8.0
Euphausia superba	85.7	2	5.8	103.5	243.9	1.8	87.0	2	11.4	218.4	422.1	20.4	100.0	4	5.2	124.0	164.0	35.2	90.9	5	3.6	78.8	169.3	14.2	85.7	2	18.9	406.5	1120.4	3.2
Fish (L) (unid.)	85.7		0.2	4.0	3.0	4.1	87.0		0.1	2.1	2.6	1.1	14.3		0.0	0.0	0.1	0.0	38.6		0.0	0.5	1.0	0.0	19.0		0.0	0.2	0.5	0.0
Thysanoessa macrura (L)	78.6	10	0.5	9.4	10.6	6.8	91.3	8	0.8	15.7	18.0	8.4	57.1	6	1.7	41.4	52.8	9.2	40.9		0.0	1.0	1.6	0.0	61.9	10	0.3	5.6	6.8	2.4
Siphonophores (unid.)	71.4	8	0.9	16.8	25.2	6.2	100.0	6	3.2	62.0	41.4	48.9	57.1		0.3	6.8	9.7	1.2	56.8		0.2	5.1	12.7	0.8	66.7	9	0.3	7.1	8.7	5.8
Lepidonotothen kempi (L)	64.3		0.1	1.9	4.9	0.6	17.4		0.0	0.7	1.7	0.0	42.9		0.0	0.2	0.2	0.0	65.9		0.0	0.4	0.5	0.3	66.7		0.0	0.6	0.7	0.5
Hyperiella dilatata	64.3		0.1	1.1	1.9	0.3	52.2		0.0	0.4	0.5	0.2	85.7		0.1	1.2	1.6	0.3	40.9		0.0	0.4	1.2	0.0	14.3		0.0	0.0	0.1	0.0
Electrona spp. (L)	64.3		0.1	1.1	1.2	0.5	69.6		0.1	1.3	1.6	0.5	14.3		0.0	0.0	0.1	0.0	61.4		0.0	0.5	0.7	0.3	52.4		0.0	0.7	1.2	0.2
Diphyes antarctica	57.1		0.0	0.3	0.4	0.2	78.3		0.1	1.0	1.1	0.7	71.4		0.0	1.2	1.0	1.2	18.2		0.0	0.1	0.3	0.0	14.3		0.0	0.1	0.1	0.0
Ostracods	50.0	6	1.1	19.5	30.5	0.1	69.6	7	1.1	21.7	34.8	3.0	71.4	5	2.9	69.3	92.1	5.5	56.8	8	0.6	14.0	42.5	1.6	61.9	6	1.1	24.0	50.3	1.6
Euphausia frigida	50.0	9	0.9	16.1	26.2	0.3	34.8		0.0	0.5	0.9	0.0	71.4	7	1.2	28.9	50.0	3.8	65.9	6	2.3	49.4	97.4	1.3	57.1	7	0.8	16.5	43.0	0.6
Isopods (unid.)	50.0		0.1	1.7	2.1	0.4	39.1		0.1	1.2	1.7	0.0	28.6		0.0	0.9	1.3	0.0	22.7		0.0	0.6	1.5	0.0	14.3		0.0	0.1	0.3	0.0
Tomopteris spp.	50.0		0.1	0.9	1.4	0.1	73.9		0.1	2.6	3.5	1.1	85.7		0.3	6.4	8.2	1.4	63.6		0.1	1.9	4.2	0.5	38.1		0.0	0.7	1.4	0.0
Sipunculids	50.0		0.0	0.7	1.5	0.1	73.9		0.0	0.7	0.9	0.5	85.7		0.1	2.6	3.0	1.3	20.5		0.0	0.3	0.7	0.0	23.8		0.0	0.2	0.4	0.0
Spongiobranchaea australis	50.0		0.0	0.2	0.3	0.1	69.6		0.0	0.7	0.9	0.5	42.9		0.0	0.2	0.3	0.0	68.2		0.0	0.7	1.4	0.3	57.1		0.0	0.5	0.9	0.2
Notolepis coatsi (L)	42.9		0.0	0.6	0.9	0.0	21.7		0.0	0.1	0.3	0.0	0.0		0.0	0.0	0.0	0.0	29.5		0.0	0.3	0.6	0.0	14.3		0.0	0.1	0.2	0.0
Euphausia spp. (L)	35.7		0.1	1.4	3.2	0.0	21.7		0.0	0.3	0.7	0.0	14.3		0.1	2.6	6.4	0.0	2.3		0.0	0.2	1.2	0.0	9.5		0.1	1.2	3.9	0.0
Euphausia frigida (L)	28.6		0.1	1.2	2.1	0.0	17.4		0.0	0.6	1.5	0.0	14.3		0.0	0.4	0.9	0.0	9.1		0.0	0.3	1.1	0.0	4.8		0.0	0.8	3.6	0.0
Hyperiella spp.	28.6		0.0	0.7	1.2	0.0	39.1		0.1	1.0	1.4	0.0	0.0		0.0	0.0	0.0	0.0	13.6		0.0	0.1	0.5	0.0	19.0		0.0	0.5	1.1	0.0
Orchomene spp.	28.6		0.0	0.2	0.4	0.0	69.6		0.4	7.6	9.6	3.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	19.0		0.0	0.0	0.1	0.0
Eusirus antarcticus	28.6		0.0	0.2	0.4	0.0	43.5		0.0	0.4	0.7	0.0	14.3		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	4.8		0.0	0.0	0.1	0.0
Notolepis annulata (L)	28.6		0.0	0.1	0.2	0.0	8.7		0.0	0.0	0.1	0.0	14.3		0.0	0.0	0.1	0.0	2.3		0.0	0.0	0.0	0.0	4.8		0.0	0.0	0.1	0.0
Euphausia superba (L)	21.4		0.3	4.6	12.9	0.0	13.0		0.0	0.5	1.3	0.0	71.4	2	8.5	205.3	395.2	8.1	63.6	3	5.3	115.9	470.9	4.4	85.7	5	2.4	50.7	76.5	12.6

Table 4.6. Taxonomic composition of zooplankton clusters during (A) January and (B) February-March, 2008. R and N(%) are rank and proportion of total mean abundance represented by each taxon. Askerisks denote significantly different abundance (higher or lower) in one cluster than the other two based on ANOVA: * P<0.05; ** P<0.01; *** P<0.001.

(A)

January Survey A

	Cluster 1 (N=11)						Cluster 2 (N=37)						Cluster 3 (N=38)					
Taxon	R	N(%)	Mean	STD	Median	P	R	N(%)	Mean	STD	Median	P	R	N(%)	Mean	STD	Median	P
Other copepods	2	15.3	161.9	119.8	140.8		3	17.7	285.3	164.3	244.5		1	27.6	243.0	203.9	151.8	
Thysanoessa macrura		0.5	5.1	7.2	1.2	***	2	18.4	295.6	311.3	172.8		2	27.2	239.1	211.0	211.3	
Euphausia superba	6	6.6	70.2	186.4	0.6		8	1.2	19.5	33.3	4.3	**	3	16.3	143.3	391.4	12.1	
Calanoides acutus	3	13.7	145.5	82.1	151.6		4	8.9	144.0	129.8	107.3		4	10.5	92.4	112.8	47.2	
Metridia gerlachei	5	10.8	114.2	207.3	3.2		1	33.3	535.6	908.8	197.2		5	4.2	36.5	202.1	0.6	
Paraeuchaeta spp.	1	18.0	191.0	155.9	132.8		5	7.3	118.0	173.2	63.6		6	2.8	24.5	46.9	5.5	**
Chaetognaths	7	4.3	45.9	48.1	21.9		6	2.7	43.2	45.9	21.5		7	1.6	14.4	16.8	8.1	**
Rhincalanus gigas		0.4	4.3	5.3	1.8		9	1.2	19.5	26.3	7.9		8	1.6	14.3	13.9	9.0	
Calanus propinquus		0.1	0.8	1.3	0.0	*	10	0.8	13.6	12.4	10.1		9	1.2	10.8	16.5	4.8	
Primno macropa		0.4	4.3	4.9	2.4			0.7	12.0	11.5	8.2		10	1.1	9.4	7.4	7.2	
Radiolaria		1.8	19.0	16.5	15.6	***		0.4	6.2	6.9	3.6			0.9	8.2	6.3	6.7	
Euphausia superba (L)	4	11.3	119.2	102.6	112.6	*	7	2.1	33.9	58.0	10.4			0.8	7.1	15.7	1.4	
Limacina spp.	9	2.3	24.9	12.2	25.2	***		0.3	5.0	10.1	0.0			0.6	5.1	11.5	0.0	
Limacina helicina		0.0	0.2	0.3	0.0			0.2	4.0	7.8	1.5			0.6	5.0	9.1	0.6	
Themisto gaudichaudii		0.0	0.0	0.0	0.0			0.1	1.5	3.0	0.4			0.4	3.8	6.9	1.8	
Salpa thompsoni		0.0	0.0	0.0	0.0			0.5	7.8	14.8	1.3			0.4	3.8	5.8	0.5	
Tomopteris spp.		0.2	2.2	2.4	0.6			0.1	1.9	3.1	1.0			0.3	2.6	4.3	1.0	
Thysanoessa macrura (L)	8	3.1	33.0	43.1	11.4	**		0.2	2.8	6.2	0.0			0.2	1.8	4.3	0.0	
Sipunculids		1.4	14.8	10.9	10.3	***		0.1	1.1	2.6	0.0			0.1	1.2	2.6	0.0	
Spongiobranchaea australis		0.2	2.4	3.5	1.0			0.1	1.4	1.7	0.8			0.1	0.8	0.9	0.5	
Rhynchonereella bongraini		0.0	0.2	0.5	0.0			0.0	0.4	1.0	0.0			0.1	0.8	1.6	0.0	
Lepidonotothen kempi (L)		0.0	0.1	0.4	0.0			0.1	1.0	2.6	0.0			0.1	0.7	1.5	0.0	
Lepidonotothen larseni (L)		0.2	2.0	1.6	1.2			0.2	3.2	7.0	0.0			0.1	0.7	0.9	0.1	
Euphausia frigida		0.0	0.1	0.3	0.0			0.8	12.8	20.7	0.6			0.1	0.6	2.0	0.0	
Barnacle (L)	10	2.1	22.5	11.7	25.9	***		0.0	0.3	1.3	0.0			0.0	0.4	0.8	0.0	
Hyperiella dilatata		0.1	0.6	1.0	0.2			0.0	0.6	0.8	0.3			0.0	0.4	0.6	0.2	
Haloptilus ocellatus		0.2	2.2	2.4	2.4			0.2	3.2	5.5	0.0			0.0	0.4	0.9	0.0	
Ostracods		1.0	11.0	19.0	2.7			0.6	10.1	24.7	3.2			0.0	0.3	0.7	0.0	
Acanthophyra pelagica		0.0	0.1	0.2	0.0			0.0	0.3	0.9	0.0			0.0	0.3	0.8	0.0	
Cyllopus magellanicus		0.0	0.1	0.2	0.0			0.0	0.6	1.4	0.0			0.0	0.3	0.6	0.0	
Heterorhabdus sp.		0.1	1.0	2.4	0.0			0.1	1.5	3.0	0.0			0.0	0.3	0.7	0.0	
Electrona spp. (L)		0.0	0.0	0.0	0.0			0.0	0.2	0.4	0.0			0.0	0.3	0.7	0.0	
Vibilia antarctica		0.0	0.0	0.0	0.0			0.0	0.6	1.5	0.0			0.0	0.2	0.3	0.0	
Clione limacina		0.1	0.8	0.6	0.7			0.0	0.6	1.0	0.0			0.0	0.2	0.4	0.0	
Pegantha martagon		0.0	0.0	0.0	0.0			0.0	0.3	0.7	0.0			0.0	0.2	0.4	0.0	
Diphyes antarctica		0.0	0.3	0.2	0.2			0.0	0.1	0.3	0.0			0.0	0.1	0.4	0.0	
Euphausia crystallorophias		0.2	2.3	4.1	0.0			0.1	0.8	2.6	0.0			0.0	0.1	0.3	0.0	
TOTAL			1059.7	526.8	879.1				1610.1	1081.5	1284.0				880.0	751.6	762.3	

(B)

February-Marach Survey D

	Cluster 1 (N=38)						Cluster 2 (N=45)						Cluster 3 (N=26)					
Taxon	R	N(%)	Mean	STD	Median	P	R	N(%)	Mean	STD	Median	P	R	N(%)	Mean	STD	Median	P
Metridia gerlachei	1	32.1	614.8	729.7	335.8		8	2.0	19.4	53.2	3.1	*	1	42.8	1828.4	2138.3	80.8	***
Thysanoessa macrura	5	5.7	109.7	116.0	79.4		3	17.5	168.6	129.4	137.3		2	14.6	624.0	480.7	147.0	***
Other copepods	3	11.0	210.5	128.7	188.7		2	23.6	227.0	163.0	178.5		3	10.7	455.8	292.0	225.5	***
Euphausia superba	4	10.3	197.7	363.8	7.6		4	7.8	75.1	243.0	3.2		4	7.6	325.3	993.4	6.6	
Calanoides acutus	2	17.8	340.5	418.2	241.5		1	26.0	250.5	418.8	116.7		5	5.4	230.5	218.1	162.0	
Euphausia superba (L)	9	1.9	36.6	185.4	0.0		10	1.2	11.8	31.1	1.0		6	5.2	221.3	596.0	0.6	*
Chaetognaths	6	5.0	96.3	71.0	86.6		5	6.6	63.7	68.3	35.9		7	2.7	113.7	195.3	58.2	
Paraeuchaeta spp.	7	3.9	74.1	78.2	45.2		7	2.3	22.2	32.2	12.2	**	8	2.5	105.5	81.6	29.9	
Euphausia frigida		0.3	6.6	17.6	0.0			0.3	2.7	7.5	0.0		9	2.3	99.6	112.9	0.5	***
Rhincalanus gigas		0.7	13.5	14.7	9.6	**	6	4.3	41.9	42.4	26.2		10	1.2	51.8	46.0	16.9	
Ostracods	10	1.4	27.8	45.9	7.5			0.2	1.8	4.8	0.0	*		1.1	47.7	71.7	2.2	
Salpa thompsoni		0.2	3.5	20.1	0.0			0.1	1.1	2.8	0.0			1.1	45.9	72.0	0.0	***
Heterorhabdus sp.		0.2	3.1	11.3	0.0			0.2	2.2	4.9	0.0			0.7	29.1	65.9	0.0	*
Calanus propinquus		0.4	7.8	8.4	5.2		9	1.3	12.6	18.4	5.1			0.3	14.2	15.0	6.5	
Primno macropa		0.6	10.8	10.5	7.9			0.6	5.5	5.6	4.2			0.3	10.9	16.6	4.7	
Haloptilus spp		0.1	1.6	3.2	0.0			0.3	3.4	5.7	0.0			0.2	10.2	19.2	0.0	*
Themisto gaudichaudii		0.1	1.3	2.2	0.2	*		0.7	7.1	12.4	3.4			0.2	8.1	6.8	2.2	
Radiolaria	8	2.7	50.9	53.4	33.4	***		0.9	8.2	18.4	2.2			0.1	4.3	14.0	4.7	
Tomopteris spp.		0.2	3.0	4.8	1.0			0.1	0.9	1.6	0.2			0.1	2.4	5.2	0.5	
Cyllopus magellanicus		0.0	0.0	0.1	0.0			0.0	0.4	1.0	0.0			0.0	1.8	2.8	0.0	**
Thysanoessa macrura (L)		0.9	17.0	26.8	8.3	*		0.6	5.7	14.0	1.2			0.0	1.7	4.9	2.2	
Paraeuchaeta antarctica		0.0	0.4	0.9	0.0			0.0	0.2	0.7	0.0			0.0	1.6	1.7	0.0	***
Vibilia antarctica		0.0	0.0	0.1	0.0			0.0	0.2	0.6	0.0			0.0	1.0	2.1	0.0	*
Hyperiella dilatata		0.0	0.8	1.4	0.3			0.0	0.1	0.2	0.0			0.0	0.7	1.6	0.0	
Electrona spp. (L)		0.1	1.1	1.5	0.2			0.1	0.7	1.0	0.3			0.0	0.5	0.7	0.2	
Haloptilus ocellatus		0.1	1.6	2.9	0.0			0.0	0.1	0.4	0.0			0.0	0.5	2.5	0.0	
Spongiobranchaea australis		0.0	0.8	1.6	0.2			0.1	0.5	0.7	0.2			0.0	0.4	0.5	0.2	
Sipunculids		0.0	0.8	1.3	0.3			0.0	0.4	0.7	0.0			0.0	0.4	1.8	0.0	
Lanaceans		0.3	5.7	10.9	0.0			0.3	3.3	8.7	0.0			0.0	0.4	1.3	0.0	
Limacina helicina		0.0	0.1	0.2	0.0			0.1	0.5	1.9	0.0			0.0	0.1	0.3	0.0	
Diphyes antarctica		0.0	0.8	1.0	0.3	**		0.0	0.2	0.5	0.0			0.0	0.0	0.1	0.0	
Hyperiella spp.		0.0	0.9	1.4	0.0	**		0.0	0.3	0.7	0.0			0.0	0.0	0.1	0.0	
Clione limacina		0.0	0.6	0.9	0.3	***		0.0	0.1	0.2	0.0			0.0	0.0	0.1	0.0	
Acanthophyra pelagica (L)		0.1	1.5	1.4	1.2	***		0.0	0.3	0.6	0.0			0.0	0.0	0.1	0.0	
Orchomene spp.		0.2	3.8	6.8	0.3	*		0.1	0.8	5.1	0.0			0.0	0.0	0.0	0.0	
Total			1917.3	1086.0	1647.6				962.6	747.5	790.6				4270.0	3051.7	1287.7	***
Taxa			23.1	8.4	27.0	***			8.6	7.6	5.0				5.6	3.3	5.9	
Total Copepods			1274.7	924.7	858.3				583.9	558.6	455.1				2742.1	2384.3	728.3	***

Table 4.7. Abundance of krill and other dominant zooplankton taxa collected in the Elephant Island area during January-February and February-March surveys, 1992-2008. Zooplankton data are not available for February-March 1992, 2006 and 2007 or January 2000.

	Euphausia superba																
	January-February																
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
N	63	70	63	71	72	71	61	40	n.a.	60	44	38	46	48	48	48	34
Mean	23.7	28.8	34.5	9.5	82.1	29.6	27.1	5.3	---	13.3	25.1	204.5	38.5	17.5	15.3	42.7	119.9
SD	78.0	64.4	94.2	20.6	245.1	80.5	42.3	8.1	---	23.6	60.0	891.6	109.7	21.2	30.7	62.1	400.1
Med	5.7	8.2	3.1	3.6	11.4	5.6	10.2	1.7	---	3.8	4.8	19.9	2.0	9.9	7.1	21.4	14.3
Max	594.1	438.9	495.9	146.1	1500.6	483.2	175.0	35.1	---	140.0	295.0	5585.4	548.2	82.1	193.8	255.7	2292.0
	February-March																
N	67	67	70	71	72	16	61	39	60	57	44	48	47	48	n.a.	n.a.	44
Mean	38.0	35.0	17.1	5.2	133.2	30.4	162.6	35.5	9.3	51.7	6.3	61.1	32.7	30.9	---	---	78.9
SD	77.4	89.7	63.5	12.0	867.7	56.4	768.3	155.7	22.7	240.6	16.3	154.5	58.3	115.7	---	---	169.2
Med	7.1	3.0	0.4	1.2	4.1	4.6	4.5	0.8	2.1	3.0	0.3	5.6	6.7	1.9	---	---	14.2
Max	389.9	542.0	371.1	90.0	7385.4	204.2	5667.0	978.6	163.1	1812.0	72.1	842.1	273.5	715.4	---	---	832.4

	Salpa thompsoni																
	January-February																
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
N	63	70	63	71	72	71	61	40	n.a.	60	44	38	46	48	48	48	34
Mean	94.3	1213.4	931.9	20.2	25.5	223.2	939.7	197.5	---	401.3	263.7	39.8	113.3	777.5	40.6	115.4	5.2
SD	192.3	2536.7	950.2	46.5	36.3	336.4	1556.3	191.6	---	370.3	395.4	85.3	107.2	819.9	64.1	261.9	7.2
Med	14.0	245.8	582.3	1.6	10.5	87.1	348.9	159.1	---	289.0	55.2	5.6	86.3	431.5	6.0	2.5	2.6
Max	1231.1	16078.8	4781.7	239.9	161.6	2006.3	8030.4	873.4	---	2259.3	1811.9	456.2	485.5	3230.7	322.4	1113.5	29.7
	February-March																
N	n.a.	67	70	71	72	16	61	39	60	57	44	48	47	48	n.a.	n.a.	44
Mean	---	1585.9	495.1	20.6	33.2	1245.5	977.3	309.1	587.2	290.3	366.9	39.1	86.7	553.8	---	---	28.2
SD	---	2725.5	579.4	66.5	85.7	1224.6	1496.5	376	2183.9	322.6	503.2	77.0	126.2	713.8	---	---	59.3
Med	---	605.9	242.6	0.7	5.6	521.0	553.8	160.7	169.1	200.7	186.5	4.5	35.0	317.2	---	---	1.3
Max	---	16662.5	2377.5	391.9	659.4	4348.3	10712.9	1550.2	15458.4	1554.6	1867.8	305.8	662.9	3473.5	---	---	238.8

	Thysanoessa macrura																
	January-February																
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
N	63	70	63	71	72	71	61	40	n.a.	60	44	38	46	48	48	48	34
Mean	48.1	48.6	74.6	104.1	103.4	101.0	135.3	46.6	---	29.7	129.2	153.8	69.6	110.3	102.5	116.0	199.2
SD	57.0	60.1	144.3	231.9	118.1	127.2	150.8	54.1	---	31.6	504.8	260.7	103.9	159.0	136.3	225.2	191.7
Med	22.5	27.5	25.4	36.1	52.3	52.8	98.0	23.2	---	20.7	21.3	66.8	35.6	70.5	51.2	36.7	130.8
Max	233.7	307.1	901.6	1859.0	500.1	616.2	992.3	215.8	---	161.9	3410.5	1373.2	624.8	959.0	622.0	1413.1	853.4
	February-March																
N	n.a.	67	70	71	72	16	61	39	60	57	44	48	47	48	n.a.	n.a.	44
Mean	---	128.9	77.1	79.7	116.1	181.3	140.6	95.2	22.6	609.5	36.3	149.6	91.0	283.7	---	---	336.1
SD	---	235.1	132.6	138.5	147.4	168.0	232.3	131.9	39.5	4222.4	85.2	174.5	132.6	328.9	---	---	363.1
Med	---	22.1	23.8	22.2	53.6	122.6	70.0	18.0	9.0	28.4	2.3	100.3	36.6	176.9	---	---	207.1
Max	---	1141.5	815.9	664.9	679.4	538.9	1638.5	589.2	187.6	32201.3	426.3	927.2	586.7	1621.0	---	---	1828.2

	Copepods																
	January-February																
Year	1992	1993	1994	1995	1996	1997	1998	1999		2001	2002	2003	2004	2005	2006	2007	2008
N	n.a.	70	63	71	72	71	61	40	n.a.	60	44	38	46	48	48	48	34
Mean	---	73.5	32.4	741.0	897.5	656.4	41.2	928.2	---	659.7	3527.7	348.0	318.1	234.5	2365.7	979.1	828.4
SD	---	302.7	92.2	1061.3	1726.4	799.1	55.1	1590.8	---	1051.3	9382.2	513.7	512.1	442.1	2292.3	2052.1	959.0
Med	---	0.0	0.0	346.0	338.2	399.7	21.5	333.0	---	178.5	1399.0	203.9	134.2	81.3	1466.5	462.3	585.3
Max	---	2312.6	465.3	7047.5	10598.0	4090.0	276.0	7524.8	---	4444.6	62083.0	2824.0	2286.4	2253.0	9007.9	13876.6	4987.0
	February-March																
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	n.a.	n.a.	44
Mean	---	---	3453.3	3707.3	1483.7	1267.8	110.4	1558.4	5158.2	2910.2	11239.6	1077.0	4066.8	657.4	---	---	1428.0
SD	---	---	8190.8	5750.3	2209.2	1755.6	170.3	2337.5	7606.0	5263.2	12888.6	1668.3	11407.7	807.0	---	---	2125.6
Med	---	---	172.4	1630.9	970.2	659.8	50.9	621.6	2237.2	976.4	4865.3	474.4	1436.7	221.5	---	---	621.0
Max	---	---	37987.2	40998.5	16621.0	7289.2	901.1	10786.6	36985.6	25601.9	58036.4	10285.9	77453.5	3543.1	---	---	13026.5

Table 4.7 (Contd.)

	Euphausia superba Larvae																
	January-February																
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
N	n.a.	n.a.	n.a.	71	72	71	61	40	n.a.	60	44	38	46	48	48	48	34
Mean	---	---	---	172.1	3.4	19.3	0.4	175.1	---	21.2	23.1	3.0	6.3	14.2	1305.4	14.2	30.1
SD	---	---	---	969.4	8.3	27.0	1.6	795.5	---	55.4	41.6	10.2	11.9	50.3	3292.2	44.2	58.5
Med	---	---	---	0.0	0.0	6.4	0.0	4.3	---	5.8	0.0	0.0	0.3	0.7	12.1	1.5	6.3
Max	---	---	---	8076.1	42.7	96.5	11.4	5083.2	---	420.7	229.2	61.4	61.5	335.6	13213.1	256.9	246.3
	February-March																
N	n.a.	n.a.	n.a.	71	72	16	61	39	60	57	44	48	47	48	n.a.	n.a.	44
Mean	---	---	---	4593.4	14.1	25.0	2.5	67.2	2209.3	45.5	32.1	3.9	105.0	125.3	---	---	115.9
SD	---	---	---	20117.0	44.0	81.4	18.3	146.0	5797.6	113.1	90.6	8.3	478.0	623.4	---	---	470.9
Med	---	---	---	268.6	3.3	0.0	0.0	12.3	160.0	2.3	0.0	0.0	12.2	2.9	---	---	4.4
Max	---	---	---	167575.6	368.5	339.0	144.1	692.5	28907.8	770.4	468.7	36.1	3319.4	4345.4	---	---	2931.6

	Euphausia frigida																
	January-February																
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
N	63	70	63	71	72	71	61	40	n.a.	60	44	38	46	48	48	48	34
Mean	5.4	4.2	4.7	12.1	2.0	9.6	0.3	15.9	---	15.0	18.0	6.8	12.4	18.3	21.5	11.4	8.7
SD	14.9	18.4	14.9	32.1	4.5	21.4	1.4	29.1	---	35.9	36.1	17.6	28.7	47.4	38.2	29.0	18.6
Med	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	---	0.0	0.3	0.0	0.0	0.0	3.1	0.0	0.1
Max	76.7	143.0	76.7	175.6	22.5	91.4	10.0	116.0	---	203.0	164.8	87.0	143.9	247.8	211.2	147.7	79.8
	February-March																
N	n.a.	67	70	71	72	16	61	39	60	57	44	48	47	48	n.a.	n.a.	44
Mean	---	1.0	28.9	19.7	9.5	44.8	9.0	23.0	27.7	24.1	50.4	32.8	17.4	22.4	---	---	49.4
SD	---	4.7	62.0	36.7	12.7	54.2	26.0	38.7	47.0	52.4	123.7	59.2	29.5	32.6	---	---	97.4
Med	---	0.0	5.5	2.9	1.2	21.0	0.0	7.6	4.4	0.0	3.3	7.4	0.5	4.3	---	---	1.3
Max	---	32.6	439.7	216.1	48.8	176.2	178.4	159.1	197.6	205.3	739.6	307.9	107.5	143.6	---	---	530.9

	Thysanoessa macrura larvae																
	January-February																
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
N	n.a.	n.a.	n.a.	71	72	71	61	40	n.a.	60	44	38	46	48	48	48	34
Mean	---	---	---	20.2	372.0	21.5	0.0	116.5	---	177.6	497.4	0.7	4.3	27.6	144.5	3.2	1.4
SD	---	---	---	75.2	858.1	38.4	0.0	348.8	---	400.0	887.1	1.7	7.1	90.0	309.6	6.5	5.5
Med	---	---	---	0.0	32.1	1.5	0.0	2.8	---	27.4	116.9	0.0	1.4	0.3	12.6	0.8	0.0
Max	---	---	---	441.5	4961.8	159.9	0.0	1519.6	---	2329.2	4127.9	9.3	29.1	537.7	1572.7	40.2	32.2
	February-March																
N	n.a.	n.a.	70	71	72	16	61	39	60	57	44	48	47	48	n.a.	n.a.	44
Mean	---	---	31.7	344.3	511.5	10.8	0.5	185.9	697.8	395.9	929.4	0.8	249.4	0.8	---	---	1.0
SD	---	---	111.1	594.2	1432.5	24.9	2.0	535.7	2667.7	657.1	1714.3	2.0	636.3	1.8	---	---	1.6
Med	---	---	0.0	79.9	36.1	1.0	0.0	10.0	17.2	166.5	234.2	0.0	25.3	0.0	---	---	0
Max	---	---	809.1	3735.5	10875.0	104.7	12.1	2990.8	20025.8	3513.3	7893.0	11.6	2983.2	8.3	---	---	4.8

	Chaetognaths																
	January-February																
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
N	n.a.	70	63	71	72	71	61	40	n.a.	60	44	38	46	48	48	48	34
Mean	---	3.1	0.2	84.7	11.9	20.1	3.3	63.9	---	37.6	89.9	12.4	22.7	10.1	202.2	28.7	20.4
SD	---	7.9	0.5	159.5	25.1	26.1	5.2	159.1	---	72.5	142.2	21.6	50.5	24.0	263.4	57.0	25.7
Med	---	0.0	0.0	30.0	4.2	10.3	0.9	14.7	---	7.3	49.3	3.4	6.0	1.8	115.0	4.9	11.2
Max	---	41.3	2.2	781.8	184.9	120.4	24.7	960.2	---	425.0	825.6	83.8	247.9	152.1	1456.4	329.1	122.0
	February-March																
N	n.a.	67	70	71	72	16	61	39	60	57	44	48	47	48	n.a.	n.a.	44
Mean	---	0.7	21.8	330.2	58.4	18.4	8.9	147.4	509.6	60.5	690.2	66.4	289.0	30.8	---	---	97.1
SD	---	4.2	87.7	404.6	72.3	23.9	23.3	261.4	993.0	114.1	778.6	84.0	716.5	42.5	---	---	157.5
Med	---	0.0	0.0	161.0	31.8	5.5	1.0	48.7	147.6	6.8	280.2	36.2	83.8	10.6	---	---	46.5
Max	---	34.9	578.9	1769.9	383.8	77.9	124.7	1146.6	5288.1	574.4	3250.1	373.0	4868.5	169.1	---	---	816.0

Table 4.8. Maturity stage composition of krill collected in the Elephant Island area during 2008 compared to 1992-2007. Advanced maturity stages are proportions of mature females that are (A) 3c-3e in January-February and (B) 3d-3e in February-March. Data are not available for January-February, 2000 or February-March, 2006 and 2007. R is proportional recruitment index for the year class resulting from each seasons' spawning activity.

A. Survey A	*Euphausia superba* January-February																
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Stage	%	%	%	%	%	%	%	%	n.a.	%	%	%	%	%	%	%	%
Juveniles	37.1	7.2	4.0	4.6	55.0	15.2	18.4	0.4	---	9.7	46.3	42.4	1.8	2.6	0.5	28.1	51.6
Immature	19.1	30.7	18.8	4.0	18.3	30.6	31.7	11.7	---	6.2	9.0	39.1	38.5	8.7	6.7	15.1	15.7
Mature	43.9	62.2	77.2	91.4	26.7	54.2	49.9	87.9	---	84.1	44.7	18.5	59.7	88.7	92.7	56.8	32.7
Females:																	
F2	0.8	7.8	2.3	0.1	1.1	6.3	9.1	1.6	---	0.2	0.4	12.3	4.3	0.9	0.4	1.4	0.6
F3a	0.6	11.7	18.0	0.2	0.0	3.5	21.4	1.7	---	0.9	0.5	11.7	18.1	2.0	0.6	5.1	9.2
F3b	12.3	14.3	19.3	1.2	0.2	0.6	9.0	1.8	---	14.6	2.3	1.3	7.5	5.2	10.0	10.8	8.0
F3c	9.2	5.1	20.1	15.3	1.9	6.9	1.0	14.7	---	13.2	13.7	1.6	11.2	11.8	7.0	9.6	3.6
F3d	0.4	1.2	2.3	17.7	0.7	6.1	0.3	23.9	---	7.4	10.0	0.0	0.1	15.8	10.9	7.5	1.6
F3e	0.0	0.0	0.0	3.7	11.6	7.4	0.7	9.2	---	1.3	6.2	0.0	0.6	3.5	16.2	0.5	0.4
Advanced Stages	42.7	19.5	37.5	96.3	98.3	83.2	6.2	93.2	---	58.5	91.6	11.2	11.8	81.2	76.2	52.7	24.5
Males:																	
M2a	8.7	6.8	0.3	0.9	14.6	14.6	8.5	2.2	---	2.1	3.0	13.6	7.4	2.5	2.5	5.5	3.9
M2b	7.3	11.9	9.4	1.5	2.1	8.2	8.4	3.9	---	2.1	4.0	10.2	14.7	2.4	2.6	4.3	7.2
M2c	2.3	4.2	6.8	1.5	0.5	1.5	5.7	4.1	---	1.7	1.5	3.1	12.2	2.9	1.3	3.9	3.9
M3a	2.8	3.7	4.3	4.4	1.4	1.5	3.1	1.7	---	2.1	1.7	1.1	11.5	2.1	1.9	2.6	1.3
M3b	18.7	26.2	13.2	48.9	10.9	28.1	14.4	34.9	---	44.6	10.4	2.9	10.8	18.3	46.0	20.7	8.6
Male:Female ratio	1.7	1.3	0.5	1.5	1.9	1.8	1.0	0.9	---	1.4	0.6	1.2	1.4	1.5	1.2	1.1	1.1
No. measured	2472	4283	2078	2294	4296	3209	3600	751	---	2063	1437	2466	1410	2189	1721	3398	2062
R	0.000	0.068	0.046	0.622	0.198	0.120	0.000	0.000	0.573	0.403	0.478	0.001	0.014	0.200	0.230		

B. Survey D	February-March																
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Stage	%	%	%	%	%	%	%	%	%	%	%	%	%	%	n.a.	n.a.	%
Juveniles	33.6	3.5	3.7	1.1	20.8	8.0	3.6	0.0	0.1	13.4	38.9	20.6	0.1	0.8	---	---	13.7
Immature	27.1	51.4	6.2	2.5	9.9	19.7	25.4	1.3	2.3	14.7	17.3	52.4	16.3	9.7	---	---	18.2
Mature	39.2	45.1	90.1	96.4	69.3	72.3	71.0	98.7	97.5	71.9	43.8	27.0	83.6	89.5	---	---	68.1
Females:																	
F2	0.8	21.8	0.7	0.3	0.6	1.1	6.9	0.0	0.2	0.7	3.3	21.4	2.9	0.8	---	---	2.7
F3a	10.3	12.4	3.5	0.0	0.0	0.1	10.9	0.4	1.0	2.4	0.9	13.4	3.7	16.2	---	---	8.4
F3b	10.2	6.2	7.8	0.0	0.0	0.0	11.8	0.0	0.7	0.2	0.2	2.5	0.3	9.3	---	---	8.1
F3c	4.3	3.7	4.3	2.0	5.0	1.8	3.0	11.1	6.5	1.5	2.2	2.3	2.2	12.1	---	---	14.7
F3d	1.2	1.1	4.6	21.8	10.9	29.1	1.3	47.3	21.9	3.8	14.7	0.3	17.0	3.6	---	---	4.2
F3e	<0.01	1.2	0.9	20.4	4.9	7.3	0.1	4.8	22.0	42.6	3.6	0.6	13.0	0.0	---	---	2.1
Advanced Stages	4.6	9.3	26.1	95.5	76.0	95.0	5.2	81.8	84.2	91.8	85.2	4.7	82.9	8.7	---	---	56.1
Males:																	
M2a	4.3	6.9	0.2	0.7	6.5	8.6	1.9	0.0	0.1	4.1	8.8	12.0	2.4	1.5	---	---	5.4
M2b	19.8	19.1	1.2	0.4	1.2	8.8	6.6	0.7	0.7	2.7	3.6	14.9	7.3	0.8	---	---	3.8
M2c	2.2	3.6	4.2	1.1	1.6	1.2	10.0	0.6	1.3	7.3	1.6	4.2	3.7	6.6	---	---	6.3
M3a	2.5	2.1	24.1	4.4	5.3	3.7	17.5	2.6	7.4	2.2	0.3	2.0	4.8	13.2	---	---	4.4
M3b	10.7	18.4	44.7	47.8	43.2	30.3	26.2	32.4	38.0	19.2	22.1	5.8	42.7	35.0	---	---	26.2
Male:Female ratio	1.5	1.1	3.4	1.2	2.7	1.3	1.9	0.6	0.9	0.7	1.5	0.9	1.6	1.4	---	---	1.2
No. measured	3646	3669	1155	1271	2984	560	3153	1176	1371	1739	558	1936	2081	1018	---	---	2458

Table 4.9. Krill abundance (No. per 1000 m3) and distributional attributes in subareas surveyed during (A) January-February and (B) February-March, 2000-2008. Largest concentrations typically reflect abundant juveniles and good recruitment success from the previous year. Index of Dispersion (ID) is a measure of distribution with smaller numbers indicating evenness and larger numbers patchiness.

(A) January-February Survey A

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
West Area N=	n.a.	30	25	25	24	25	25	23	22
Mean	-----	8.3	27.0	24.6	7.3	5.4	6.4	27.7	31.7
SD	-----	12.0	90.8	55.2	13.7	8.4	8.1	43.5	60.0
Median	-----	1.5	0.3	5.1	1.4	1.5	5.1	11.3	5.5
ID	-----	17.3	305.7	124.0	25.6	13.0	10.3	68.4	113.3
Elephant Island	n.a.	60	44	38	46	48	48	48	34
Mean	-----	13.3	25.1	204.5	38.5	17.5	15.3	42.7	119.9
SD	-----	23.6	60	891.6	109.7	21.2	30.7	62.1	400.1
Median	-----	3.8	4.8	19.9	2.0	9.9	7.1	21.4	14.3
ID	-----	41.8	143.5	3887.5	312.4	25.7	61.4	90.3	1335.5
Joinville Island	n.a.	n.a.	9	3	5	6	6	7	10
Mean	-----	-----	50.4	323.0	0.2	17.8	61.1	237.2	165.9
SD	-----	-----	98.7	428.7	0.3	36.2	119.3	457.3	251.6
Median	-----	-----	6.6	38.6	0.0	1.2	10.2	2.0	1.5
ID	-----	-----	193.2	569.1	0.3	73.8	232.8	881.5	381.7
South Area (N	n.a.	11	17	17	16	20	20	20	20
Mean	-----	74.7	104.0	56.2	41.9	8.8	16.9	102.1	25.7
SD	-----	115.6	251.2	123.3	72.1	23.8	38.9	205.6	83.7
Median	-----	14.5	0.5	0.7	0.8	0.6	5.0	14.0	1.0
ID	-----	178.7	606.4	270.9	124.1	64.7	89.8	413.9	271.9

(B) February-March Survey D

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
West Area	29	29	24	25	25	25	n.a.	n.a.	n.a.
Mean	24.8	23.1	446.6	59.8	33.8	5.0	-----	-----	-----
SD	77.7	55.8	1490.7	111.2	153.1	9.8	-----	-----	-----
Median	2.5	3.4	0.0	13.6	0.3	0.9	-----	-----	-----
ID	243.5	134.7	4975.4	206.8	693.3	19.2	-----	-----	-----
Elephant Island	60	57	44	48	47	48	n.a.	n.a.	44
Mean	9.3	51.7	6.3	61.1	32.7	30.9	-----	-----	78.9
SD	22.7	240.6	16.3	154.5	58.3	115.7	-----	-----	169.2
Median	2.1	3.0	0.3	5.6	6.7	1.9	-----	-----	14.2
ID	55.5	1118.2	42.2	390.9	103.8	433.0	-----	-----	362.9
Joinville Island	n.a.	n.a.	9	4	8	6	n.a.	n.a.	n.a.
Mean	----	-----	2.8	17.5	46.1	19.1	-----	-----	-----
SD	----	-----	3.5	10.8	77.6	40.8	-----	-----	-----
Median	----	-----	1.1	14.3	6.1	0.9	-----	-----	-----
ID	----	-----	4.4	6.6	130.6	87.1	-----	-----	-----
South Area	8	10	17	18	17	18	n.a.	n.a.	21
Mean	4.3	2.1	352.6	264.8	107.9	62.4	-----	-----	406.5
SD	7.2	5.3	1135.7	406.7	348.2	173.9	-----	-----	1120.4
Median	1.5	0.2	4.1	22.2	0.5	1.0	-----	-----	3.2
ID	11.9	13.3	3657.6	624.7	1123.5	484.2	-----	-----	3087.8
Eastern Transect	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7
Mean	----	-----	-----	-----	-----	-----	-----	-----	124.0
SD	----	-----	-----	-----	-----	-----	-----	-----	164.0
Median	----	-----	-----	-----	-----	-----	-----	-----	35.2
ID	----	-----	-----	-----	-----	-----	-----	-----	216.9
SO North Shelf	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	15
Mean	----	-----	-----	-----	-----	-----	-----	-----	154.2
SD	----	-----	-----	-----	-----	-----	-----	-----	302.5
Median	----	-----	-----	-----	-----	-----	-----	-----	2.1
ID	----	-----	-----	-----	-----	-----	-----	-----	593.4
SO South Shelf	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	22
Mean	----	-----	-----	-----	-----	-----	-----	-----	189.0
SD	----	-----	-----	-----	-----	-----	-----	-----	408.0
Median	----	-----	-----	-----	-----	-----	-----	-----	15.1
ID	----	-----	-----	-----	-----	-----	-----	-----	880.8

Table 4.10. Percent contribution and abundance rank (R) of numerically dominant zooplankton and nekton taxa in the Elephant Island area during (A) January-February and (B) February-March, 1994-2008. Includes the 10 most abundant taxa each year. Radiolaria excluded as a taxonomic category. No samples were collected January-February 2000. Dashes indicate that the taxon was not enumerated during that survey.

(A)

	January-February																													
	2008		2007		2006		2005		2004		2003		2002		2001		2000		1999		1998		1997		1996		1995		1994	
Taxa	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R	n.a.		%	R	%	R	%	R	%	R	%	R	%	R
Copepods	66.39	1	71.59	1	53.61	1	18.54	2	50.37	1	42.52	1	75.69	1	46.76	1	--	—	58.05	1	4.80	3	57.16	1	56.18	1	61.54	1	4.08	3
Thysanoessa macrura	15.96	2	8.52	2	2.32	6	8.71	3	11.02	3	18.79	3	2.77	4	2.15	5	--	—	2.92	6	15.38	2	10.24	3	7.56	4	9.09	3	7.87	2
Euphausia superba	9.61	3	3.14	4	0.35		1.38	6	6.10	4	25.06	2	0.54	6	0.88	10	--	—	0.33	8	3.13	5	3.96	4	7.95	3	1.37	7	2.68	4
Euphausia superba (L)	2.41	4	1.04	6	29.58	2	1.12	7	0.99	10	0.37	10	0.49	7	1.53	6	--	—	10.95	3	0.09		1.49	7	0.19	10	12.80	2	--	
Chaetognaths	1.63	5	2.11	5	4.58	3	0.80	9	3.60	5	1.51	6	1.93	5	2.68	4	--	—	4.00	5	0.92	7	2.28	5	0.90	7	7.84	4	0.04	
Primno macropa	0.70	6	0.50	9	0.12		0.17		0.40		0.44	9	0.12		0.10		--	—	0.13		0.06		0.42	10	0.01		0.01		0.05	
Euphausia frigida	0.70	7	0.83	7	0.49	9	1.45	5	1.96	6	0.84	7	0.39	9	1.09	7	--	—	1.00	7	0.02		1.45	8	0.14		0.92	8	0.38	9
Salpa thompsoni	0.42	8	8.47	3	0.92	7	61.45	1	17.94	2	4.87	4	5.66	3	29.03	2	--	—	12.35	2	68.76	1	17.79	2	1.45	6	1.51	5	80.83	1
Limacina helicina	0.29	9	0.73	8	0.37	10	0.05		1.30	9	2.55	5	0.03		0.14		--	—	0.07		0.69	8	0.28		2.38	5	0.18		0.03	
Ostracods	0.23	10	0.50	10	0.19		0.08		1.74	7	0.53	8	0.09		0.25		--	—	0.13		0.41	9	0.54	9	0.35	8	0.91	9	--	
Euphausia triacantha	0.12		0.06		0.04		0.15		0.10		0.05		0.02		0.10		--	—	0.03		0.02		0.14		0.04		0.14		0.12	
Themisto gaudichaudii	0.12		0.07		0.02		0.64	10	0.24		0.35		0.32	10	0.17		--	—	0.02		0.03		0.35		0.34	9	0.46		1.05	6
Thysanoessa macrura (L)	0.11		0.23		3.27	4	2.19	4	0.69		0.09		10.67	2	12.55	3	--	—	7.29	4	0.00		1.67	6	21.82	2	1.50	6	--	
Spongiobranchaea australis	0.10		0.06		0.04		0.05		0.29		0.15		0.02		0.09		--	—	0.09		0.07		0.22		0.13		0.05		0.01	
Tomopteris spp.	0.09		0.28		0.09		0.05		0.11		0.20		0.03		0.11		--	—	0.15	10	0.11		0.19		0.06		0.40		0.25	10
Cyllopus magellanicus	0.03		0.13		0.02		0.88	8	0.07		0.04		0.09		0.01		--	—	0.15		0.21		0.45		0.13		0.02		0.63	
Vibilia antarctica	0.02		0.12		0.11		0.18		0.07		0.19		0.06		0.98	8	--	—	0.32	9	1.12	6	0.24		0.04		0.02		1.17	5
Larvaceans	0.02		0.05		2.60	5	--		--		—		--		—		--	—	—		--		--		--		—		--	
Ihlea racovitzai	0.01		0.06		0.00		0.16		1.63	8	0.03		0.02		0.02		--	—	0.15		3.53	4	--		--		—		--	
Clio pyramidata spp.	0.01		0.01		0.00		0.05		0.01		0.01		0.46	8	0.08		--	—	0.01		0.02		0.00		0.01		0.50	10	0.53	8
Euphausia frigida (L)	0.03		0.02		0.78	8	--		--		—		--		—		--	—	—		--		--		--		—		--	
Cyllopus lucasii	0.01		0.00		0.00		0.03		0.38		0.06		0.02		0.98	9	--	—	0.15		0.16	10	0.37		0.11		0.02		0.62	7
TOTAL	99.02		98.53		99.51		98.13		98.94		98.65		99.43		99.68		--		98.30		99.32		98.79		99.64		99.26		99.69	

(B)

	February-March																													
	2008		2007		2006		2005		2004		2003		2002		2001		2000		1999		1998		1997		1996		1995		1994	
Taxa	%	R	n.a.		n.a.		%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R	%	R
Copepods	65.33	1	--	—	--	--	37.34	1	80.19	1	73.70	1	83.13	1	64.68	1	54.20	1	62.77	1	7.38	4	44.46	1	62.07	1	40.49	2	82.15	1
Thysanoessa macrura	15.38	2	--	—	--	--	16.12	3	1.77	6	10.24	2	0.27	7	14.96	2	0.24	8	3.84	5	9.40	3	6.36	3	4.86	4	0.87	5	1.83	3
Euphausia superba (L)	5.30	3	--	—	--	--	7.12	4	2.26	4	0.27	8	0.20	8	1.03	7	23.14	2	2.71	6	0.16		0.88	6	0.59	7	50.16	1	--	
Chaetognaths	4.44	4	--	—	--	--	1.75	6	5.68	2	4.54	3	5.11	3	1.34	5	5.35	5	5.94	4	0.60	8	0.65	7	2.43	5	3.61	4	0.47	6
Euphausia superba	3.61	5	--	—	--	--	1.76	5	0.65	7	4.18	4	0.05		1.15	6	0.10		1.43	7	10.87	2	1.07	5	5.57	3	0.06	10	0.41	7
Euphausia frigida	2.26	6	--	—	--	--	1.27	7	0.34		2.24	6	0.37	6	0.54	8	0.29	7	1.00	8	0.60	7	1.57	4	0.40	8	0.21	8	0.69	5
Salpa thompsoni	1.29	7	--	—	--	--	31.46	2	2.02	5	2.67	5	2.71	4	6.50	4	6.17	4	12.46	2	65.31	1	43.62	2	1.39	6	0.22	7	11.78	2
Ostracods	0.64	8	--	—	--	--	0.15		0.43	9	0.24	9	0.06		0.03		0.20	9	0.65	9	0.35	10	0.17	10	0.38	9	0.43	6	--	
Primno macropa	0.32	9	--	—	--	--	0.04		0.13		0.35	7	0.21	9	0.03		0.02		0.08		0.11		0.02		0.15	10	0.00		0.00	
Themisto gaudichaudii	0.26	10	--	—	--	--	0.65	8	0.03		0.20	10	0.12		0.07		0.02		0.01		0.01		0.10		0.09		0.01		0.27	8
Cyllopus magellanicus	0.06		--	—	--	--	0.65	9	0.01		0.09		0.02		0.02		0.07		0.17		0.55	9	0.12		0.10		0.01		0.12	
Euphausia triacantha	0.06		--	—	--	--	0.04		0.03		0.09		0.01		0.02		0.01		0.06		0.04		0.03		0.03		0.02		0.03	
Thysanoessa macrura (L)	0.05		--	—	--	--	0.05		4.92	3	0.06		6.87	2	8.81	3	7.33	3	7.49	3	0.03		0.38	8	21.40	2	3.76	3	--	
Vibilia antarctica	0.03		--	—	--	--	0.18	10	0.01		0.07		0.16	10	0.21	10	0.18	10	0.15		0.71	6	0.28	9	0.05		0.00		0.16	9
Electrona spp. (L)	0.02		--	—	--	--	0.00		0.01		0.18		0.02		0.02		0.03		0.01		0.01		0.01		0.04		0.07	9	0.75	4
Euphausia frigida (L)	0.01		--	—	--	--	0.02		0.12		0.07		0.40	5	—		--		—		--		--		--		—		--	
Limacina helicina	0.01		--	—	--	--	0.02		0.63	8	0.06		0.00		0.00		2.21	6	0.00		0.03		0.00		0.01		0.00		0.00	
Euphausia spp. (L)	0.01		--	—	--	--	0.04		—	--	0.01		0.00		0.01		0.04		0.10		0.00		0.00		0.00		0.00		--	
Ihlea racovitzai	0.01		--	—	--	--	0.07		0.41	10	0.01		0.00		0.00		0.00		0.34	10	2.77	5	--		--		—		--	
Cyllopus lucasii	0.00		--	—	--	--	0.04		0.06		0.01		0.01		0.43	9	0.00		0.01		0.14		0.08		0.01		0.01		0.14	10
TOTAL	99.09		--		--		98.77		99.64		99.29		99.72		99.43		99.61		98.76		96.17		99.70		99.56		99.93		98.66	

Table 4.11. Percent Similarity Index (PSI) values from comparisons of overall zooplankton composition in the Elephant Island Area during (A) Survey A and (B) Survey D, 1994-2008.

(A)

	January-February PSI Values													
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1994	16.7	16.6	34.2	85.0	20.9	n.a	38.7	14.5	20.9	34.0	76.4	8.5	24.2	16.0
1995	xxxxx	70.3	76.8	18.7	80.7	n.a.	58.9	71.7	58.7	70.2	35.4	77.2	78.4	78.1
1996		xxxxx	73.4	19.3	70.0	n.a.	65.9	73.4	64.2	69.7	32.9	62.5	71.3	74.4
1997			xxxxx	38.4	80.2	n.a.	75.7	71.3	66.6	90.1	52.6	64.0	83.3	77.1
1998				xxxxx	22.6	n.a.	39.8	15.2	30.9	41.2	78.0	10.3	27.7	25.6
1999					xxxxx	n.a.	75.1	77.4	54.4	73.2	40.0	76.5	74.9	67.2
2000						xxxxx	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2001							xxxxx	69.2	54.4	74.6	56.7	58.9	63.4	55.1
2002								xxxxx	53.8	63.5	32.2	63.7	84.2	73.3
2003									xxxxx	70.3	36.7	49.6	64.1	72.6
2004										xxxxx	51.5	60.7	76.8	72.8
2005											xxxxx	27.3	40.7	32.5
2006												xxxxx	62.1	62.2
2007													xxxxx	84.3

(B)

	February-March PSI Values													
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1994	42.4	66.9	60.1	22.9	78.4	61.8	74.9	86.4	80.4	85.4	53.1	n.a.	n.a.	70.4
1995	xxxxx	49.1	44.0	10.0	52.4	72.0	48.1	48.9	46.2	52.0	47.8	n.a.	n.a.	51.3
1996		xxxxx	54.3	21.1	80.3	67.0	80.9	74.1	76.4	74.8	48.6	n.a.	n.a.	76.1
1997			xxxxx	60.5	65.2	53.6	61.3	49.5	57.6	51.5	79.7	n.a.	n.a.	56.7
1998				xxxxx	27.7	15.5	26.2	12.0	25.6	14.0	52.5	n.a.	n.a.	23.7
1999					xxxxx	76.9	85.0	78.7	77.2	62.8	61.3	n.a.	n.a.	78.4
2000						xxxxx	71.0	70.0	62.9	54.2	53.6	n.a.	n.a.	66.3
2001							xxxxx	76.8	81.2	64.7	63.3	n.a.	n.a.	85.3
2002								xxxxx	82.5	80.2	43.2	n.a.	n.a.	72.5
2003									xxxxx	73.7	56.0	n.a.	n.a.	88.4
2004										xxxxx	46.6	n.a.	n.a.	76.8
2005											xxxxx	n.a.	n.a.	64.7
2006												xxxxx	n.a.	n.a.
2007													xxxxx	n.a.

Table 4.12. Abundance of biomass dominant copepod species in the Elephant Island area during (A) January-February and (B) February-March surveys 1981-2008. 1981-1990 data provided by John Wormuth and Park and Wormuth (1993). Dashes indicate that data are not available.

(A)

January-February Surveys

Survey Period	No. per 1000 m3	*Calanoides acutus*	*Calanus propinquus*	*Metridia gerlachei*	*Rhincalanus gigas*	*Pleuromamma robusta*	*Pareuchaeta antarctica*	*Pareuchaeta* spp.	*Haloptilus ocellatus*	*Heterorhabdus austrinus*	Copepodites	Other Copepods	Total Copepods
Jan-Feb	Mean	429.7	93.6	1639.0	---	---	---	---	---	---	---	---	2670.0
1988	STD	676.8	104.3	3488.0	---	---	---	---	---	---	---	---	4630.0
N=48	Med	80.5	45.5	57.0	---	---	---	---	---	---	---	---	---
Jan	Mean	302.5	354.4	981.3	---	---	---	---	---	---	---	---	6750.0
1990	STD	405.8	365.8	1620.7	---	---	---	---	---	---	---	---	8500.0
N=23	Med	170.1	243.6	192.3	---	---	---	---	---	---	---	---	---
Jan	Mean	335.4	109.1	340.5	---	---	---	---	---	---	---	---	927.0
1999	STD	1009.5	161.9	512.7	---	---	---	---	---	---	---	---	1590.8
N=40	Med	28.9	52.0	66.0	---	---	---	---	---	---	---	---	332.9
Jan	Mean	157.5	33.3	315.6	13.0	3.5	0.1	---	0.0	---	0.0	136.7	659.7
2001	STD	255.8	57.3	709.7	48.1	13.5	0.4	---	0.0	---	0.0	390.1	1051.3
N=60	Med	75.7	8.0	29.3	0.0	0.0	0.0	---	0.0	---	0.0	26.9	178.5
Jan	Mean	1885.5	1197.8	225.6	91.1	0.9	78.9	---	0.0	---	19.4	28.4	3527.7
2002	STD	5334.5	3640.3	300.8	245.1	4.1	119.4	---	0.0	---	99.1	57.2	9382.2
N=44	Med	563.8	323.4	83.8	10.5	0.0	37.1	---	0.0	---	0.0	7.1	1399.0
Jan	Mean	48.7	51.5	155.2	7.1	1.2	0.0	---	0.1	---	0.0	26.4	348.0
2003	STD	43.7	41.8	411.2	15.0	7.0	0.0	---	0.6	---	0.0	22.5	513.7
N=38	Med	33.5	35.4	4.3	1.2	0.0	0.0	---	0.0	---	0.0	17.9	203.9
Jan	Mean	49.8	47.1	188.9	6.3	15.5	10.6	---	0.0	---	0.0	0.0	318.1
2004	STD	62.5	41.0	454.5	12.2	26.4	16.1	---	0.0	---	0.0	0.0	512.1
N=46	Med	27.5	36.7	16.3	0.1	5.0	4.9	---	0.0	---	0.0	0.0	134.2
Jan	Mean	25.1	17.0	141.5	8.1	0.9	0.4	9.8	0.0	0.0	0.0	31.6	234.5
2005	STD	40.3	26.9	395.2	13.5	4.5	1.6	34.6	0.0	0.0	0.0	37.3	442.1
N=48	Med	10.4	6.1	2.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	22.6	81.3
Jan	Mean	609.8	182.8	744.3	188.3	1.0	0.3	191.3	9.8	0.0	0.0	414.3	2365.7
2006	STD	981.6	230.3	1286.5	266.6	3.7	0.9	197.2	19.9	0.0	0.0	465.0	2292.3
N=48	Med	167.4	90.7	163.6	106.7	0.0	0.0	123.5	0.0	0.0	0.0	251.0	1466.5
Jan	Mean	129.2	10.3	569.5	29.4	1.4	0.4	138.4	0.4	0.5	0.0	95.3	979.1
2007	STD	116.3	12.2	1899.5	32.3	5.8	1.1	151.8	1.7	1.3	0.0	73.1	2052.1
N=48	Med	109.3	5.9	17.6	21.9	0.0	0.0	78.7	0.0	0.0	0.0	74.4	462.3
Jan	Mean	99.5	11.1	342.4	14.9	5.6	0.9	50.8	1.0	0.9	0.0	301.3	828.4
2008	STD	106.0	11.9	863.2	16.7	18.2	4.8	89.9	2.0	1.5	0.0	192.9	959.0
N=34	Med	56.6	7.4	52.4	10.4	0.0	0.0	16.5	0.0	0.0	0.0	246.1	585.3

Table 4.12 (Contd.)

(B)

February-March Surveys

Survey Period	No. per 1000 m3	*Calanoides acutus*	*Calanus propinquus*	*Metridia gerlachei*	*Rhincalanus gigas*	*Pleuromama robusta*	*Pareuchaeta antarctica*	*Pareuchaeta* spp.	*Haloptilus ocellatus*	*Heterorhabdus austrinus*	Copepodites	Other Copepods	Total Copepods
Mar	Mean	4786.9	5925.8	2402.5	---	---	---	---	---	---	---	---	---
1981	STD	5482.2	6451.6	3321.4	---	---	---	---	---	---	---	---	---
N=10	Med	2197.7	2048.7	609.5	---	---	---	---	---	---	---	---	---
Feb-Mar	Mean	25.5	121.7	1154.4	---	---	---	---	---	---	---	---	---
1984	STD	29.6	134.4	2999.9	---	---	---	---	---	---	---	---	---
N=13	Med	16.2	51.4	23.1	---	---	---	---	---	---	---	---	---
Feb	Mean	161.4	194.9	3189.3	---	---	---	---	---	---	---	---	4350.0
1989	STD	240.9	151.5	4017.2	---	---	---	---	---	---	---	---	6620.0
N=25	Med	88.0	162.0	1051.0	---	---	---	---	---	---	---	---	---
Feb	Mean	511.8	300.9	521.1	---	---	---	---	---	---	---	---	1557.9
1999	STD	1395.6	630.6	699.0	---	---	---	---	---	---	---	---	2337.8
N=39	Med	70.7	70.8	216.9	---	---	---	---	---	---	---	---	621.6
Feb	Mean	1187.6	477.2	1963.0	700.5	6.4	69.0	---	1.0	---	---	753.5	5158.2
2000	STD	2043.7	994.8	3076.9	1580.1	22.3	160.2	---	5.0	---	---	1816.0	7606.0
N=60	Med	144.8	124.3	803.8	51.4	0.0	7.1	---	0.0	---	---	191.5	2237.2
Feb-Mar	Mean	1648.8	159.0	932.0	20.7	2.4	47.9	---	0.2	---	75.5	23.8	2910.2
2001	STD	4512.1	260.1	1908.1	83.0	8.7	88.6	---	1.6	---	226.9	121.2	5263.2
N=57	Med	71.7	78.6	90.1	0.0	0.0	13.4	---	0.0	---	14.9	0.0	976.4
Feb-Mar	Mean	6155.3	2461.9	1617.8	788.9	19.3	108.9	---	9.5	---	3.4	74.6	11239.6
2002	STD	8074.6	2758.9	2009.8	1256.0	62.5	173.1	---	42.4	---	14.5	216.9	12888.6
N=44	Med	2949.5	1310.4	761.3	158.4	0.0	33.8	---	0.0	---	0.0	0.0	4865.3
Feb	Mean	88.8	43.9	702.9	25.1	3.8	2.4	---	0.3	---	0.0	131.9	1077.0
2003	STD	73.5	45.1	1440.6	29.5	11.2	6.4	---	1.1	---	0.0	151.4	1668.3
N=48	Med	76.7	30.8	126.9	11.5	0.0	0.0	---	0.0	---	0.0	83.7	474.4
Feb-Mar	Mean	1172.4	721.9	1155.8	779.6	5.0	105.6	---	9.7	56.9	0.2	57.7	4066.8
2004	STD	4785.0	2266.7	2505.7	3418.6	16.3	177.0	---	34.5	355.4	1.4	125.4	11407.7
N=47	Med	179.2	211.5	249.7	79.6	0.0	68.4	---	0.0	0.0	0.0	4.1	1436.7
Feb-Mar	Mean	92.8	14.5	456.0	34.7	1.4	0.7	21.6	0.1	0.6	0.0	34.9	657.4
2005	STD	247.9	29	691.9	34.9	6.2	1.9	27.9	0.7	3.4	0.0	41.6	807.0
N=48	Med	30.8	6.4	49.3	20.3	0.0	0.0	5.7	0.0	0.0	0.0	20.8	221.5
Feb-Mar	Mean	163.6	9.2	782.3	58.3	8.2	0.7	56.5	0.3	18.9	0.0	321.6	1428.0
2008	STD	147.5	13.9	1819.1	47.7	20.1	1.4	69.4	1.9	52.3	0.0	264.8	2125.6
N=44	Med	114.3	3.2	30.6	40.3	0.0	0.0	27.5	0.0	0.0	0.0	262.5	621.0

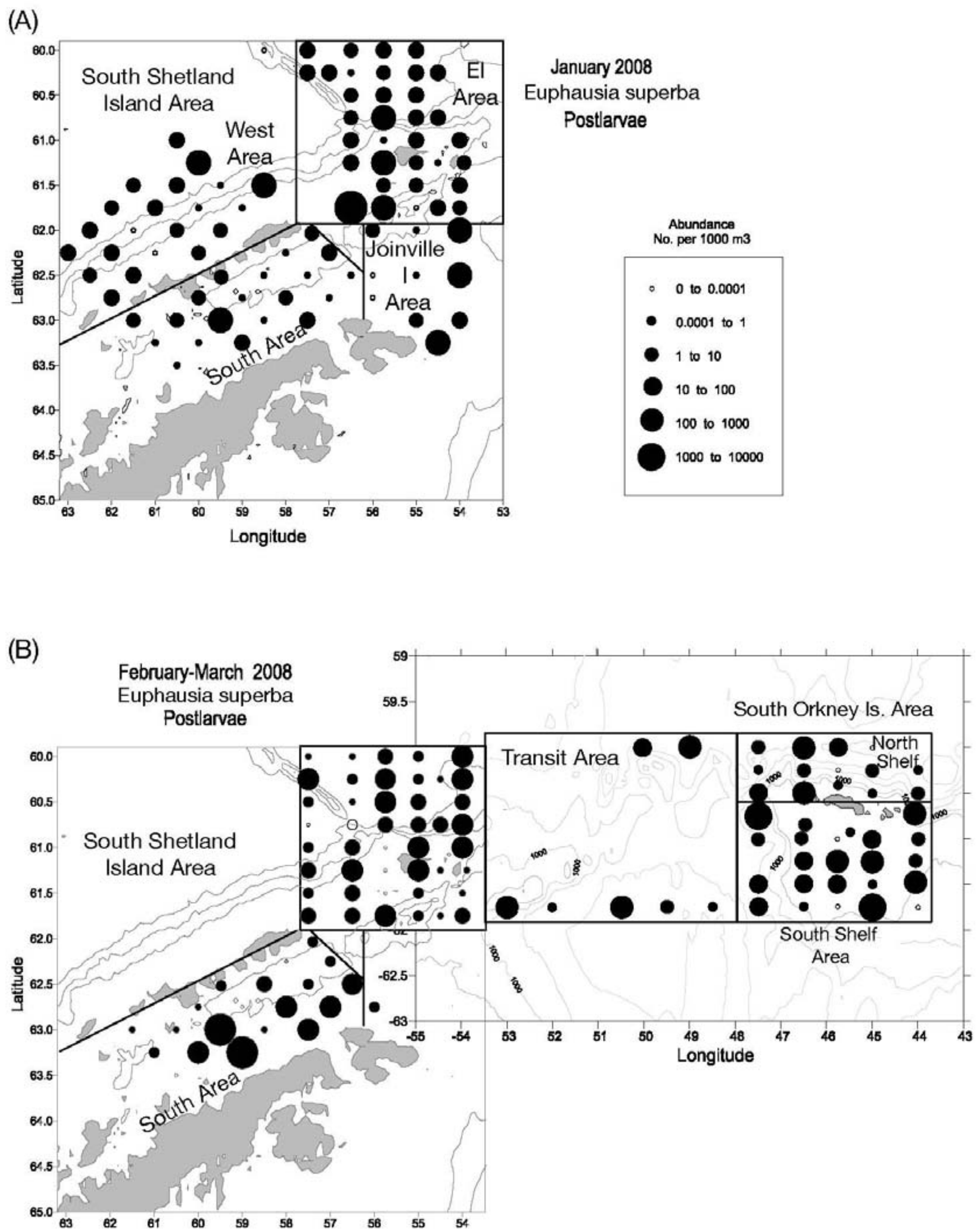


Figure 4.1. Postlarval krill abundance in IKMT tows collected during (A) January Survey A and (B) February-March Survey D, 2008. (A) West, Elephant Island, South and Joinville Island Areas and stations are indicated for

Survey A and (B) Elephant Island and South Areas, Transect and South Orkney Island northern and southern shelf stations are indicated for Survey D.

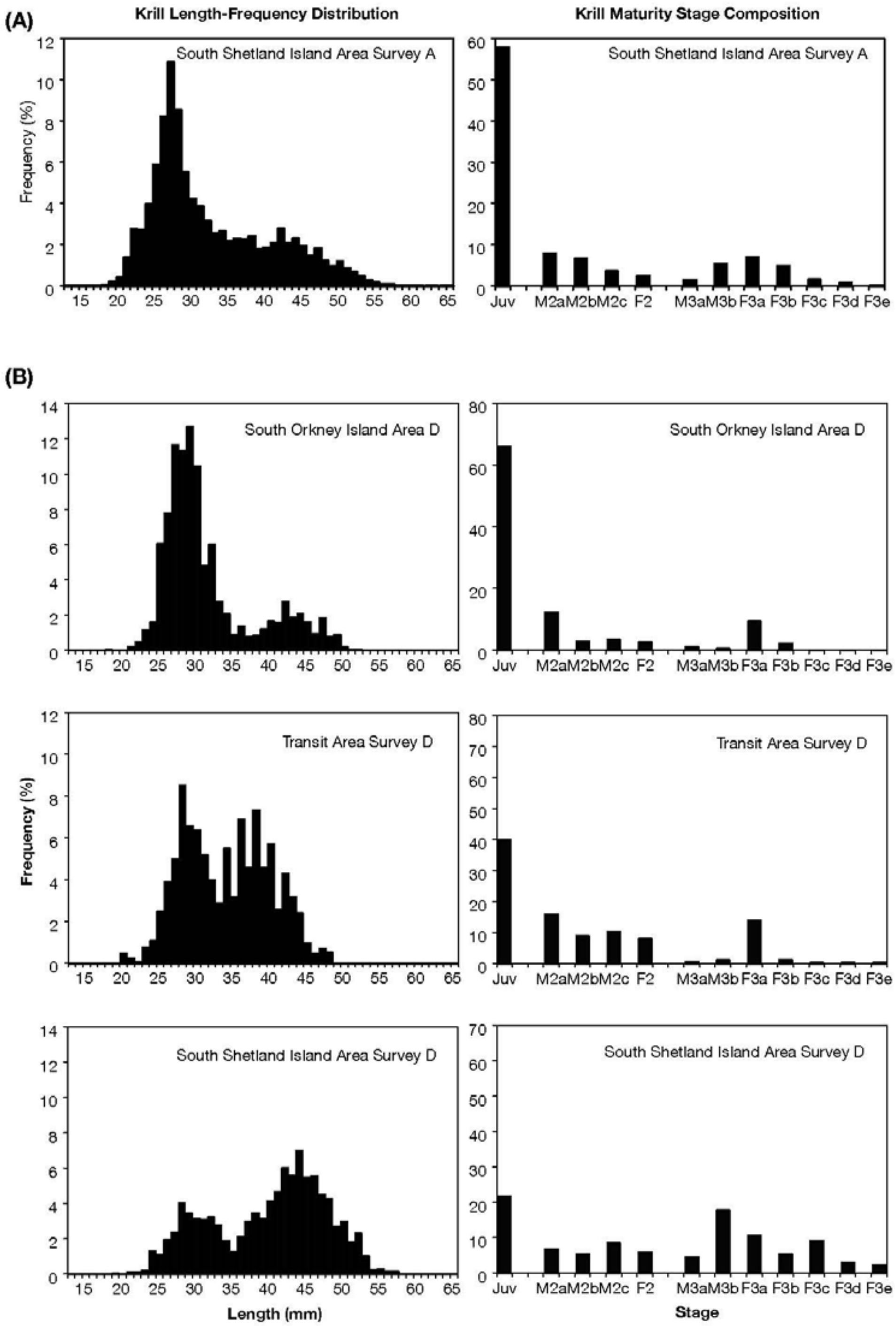


Figure 4.2. Overall krill length-frequency distribution and maturity stage composition for (A) the South Shetland Islands, January Survey A, 2008 and (B) South Orkney Islands, Transit and South Shetland Islands, February-March Survey D, 2008.

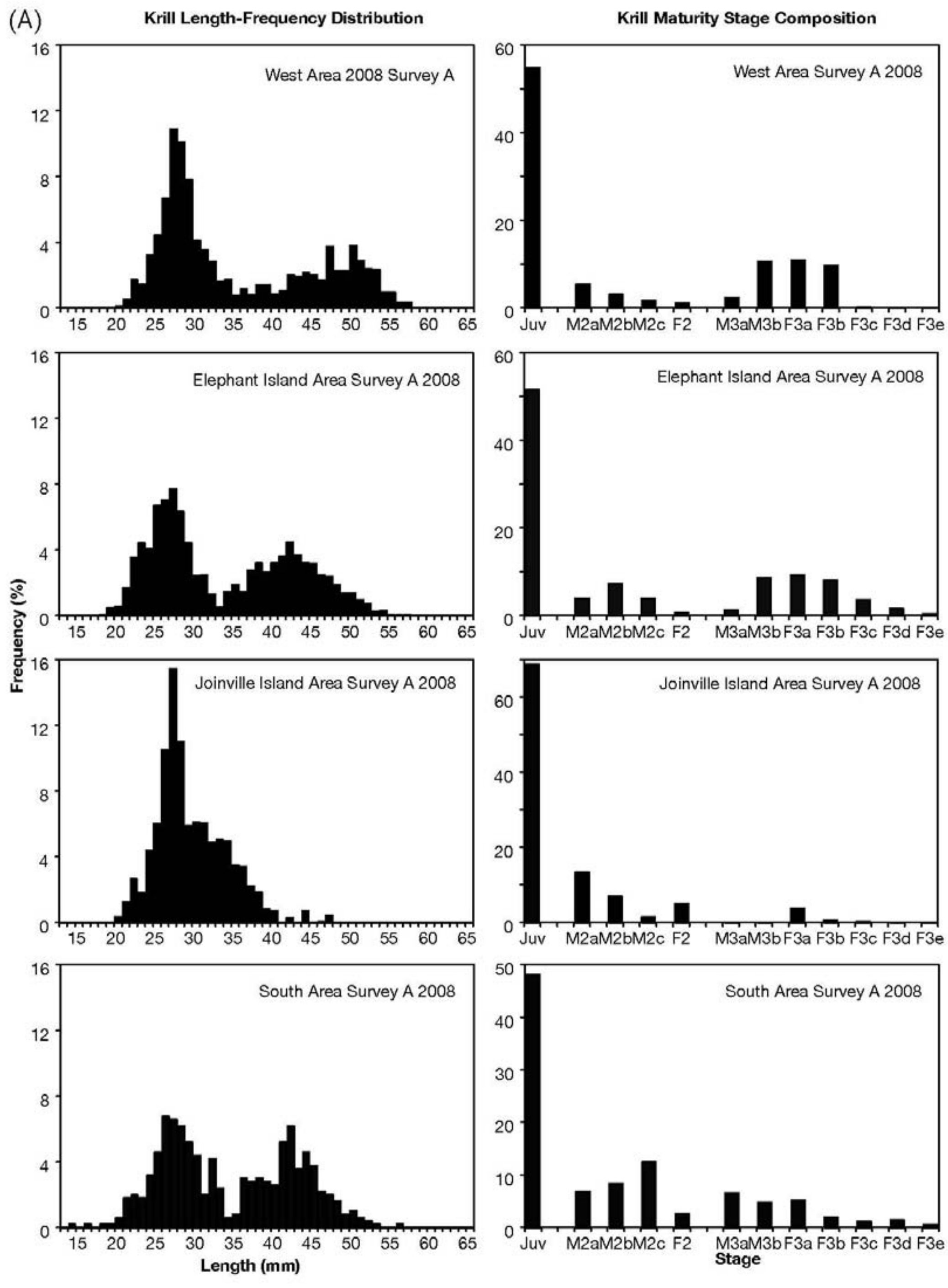


Figure 4.3. Krill length-frequency distribution and maturity stage composition in the (A) West, Elephant Island, South and Joinville Island Areas during January Survey A.

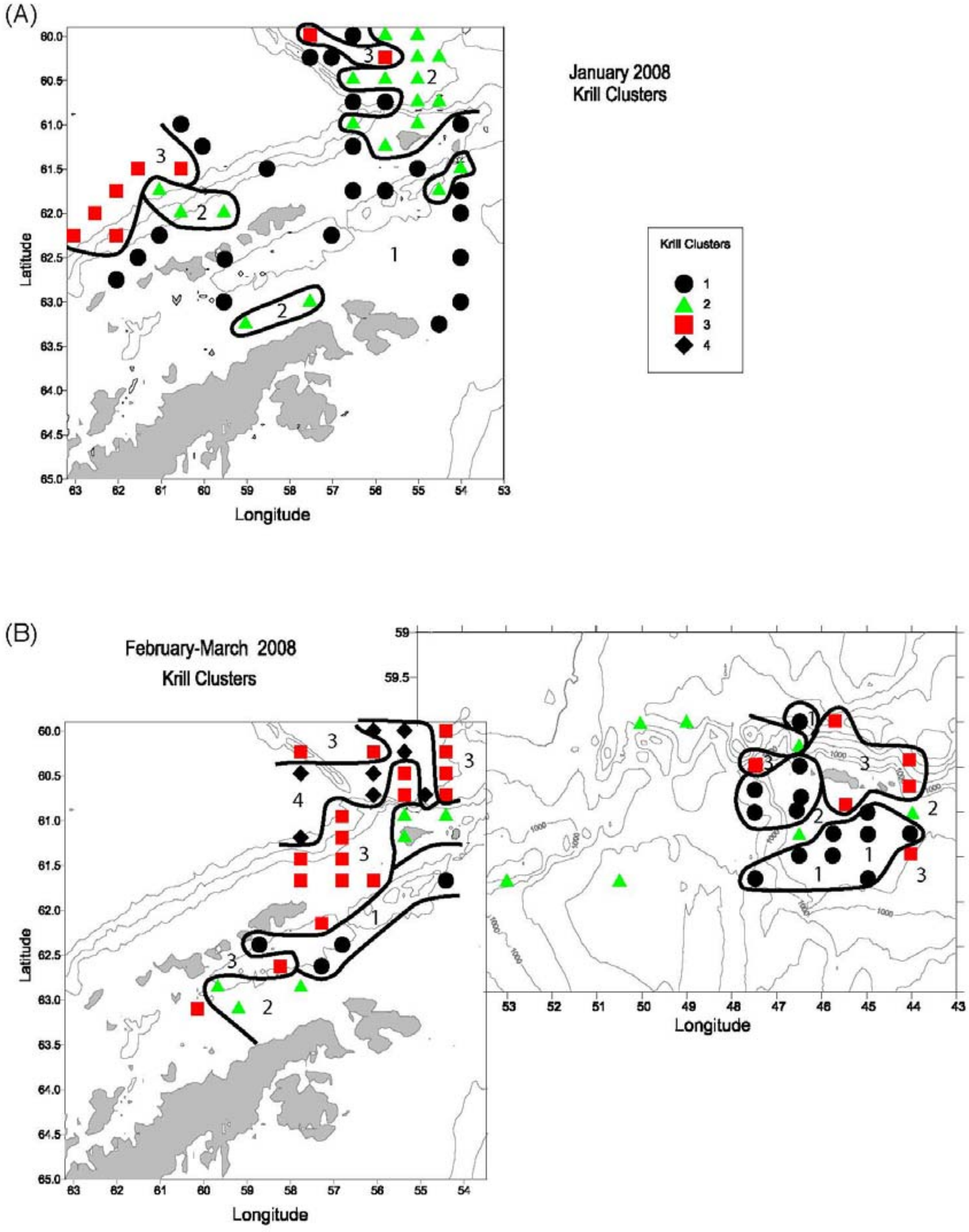


Figure 4.4. Distribution patterns of krill belonging to length categories (Clusters) during (A) January Survey A and (B) February-March Survey D, 2008.

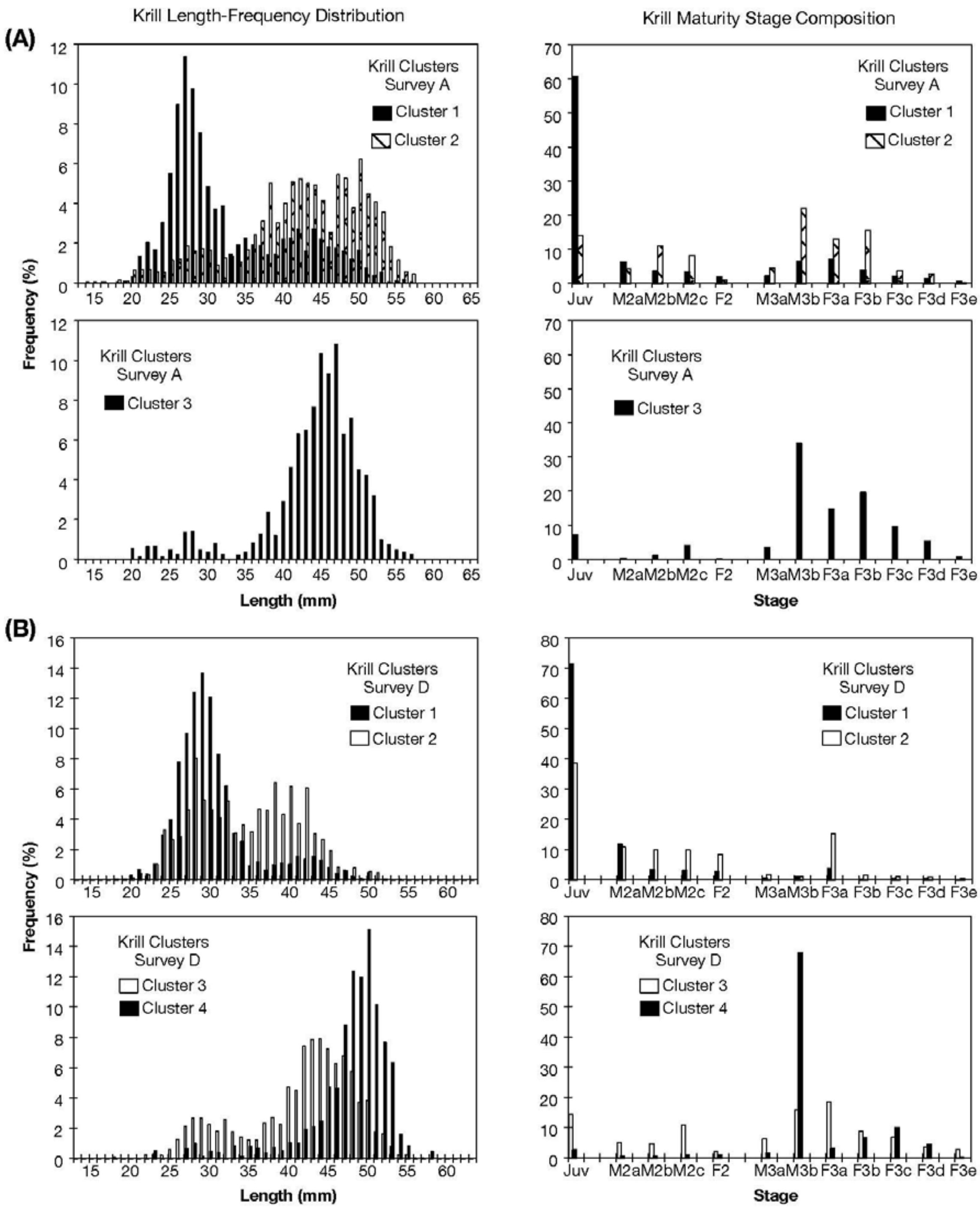
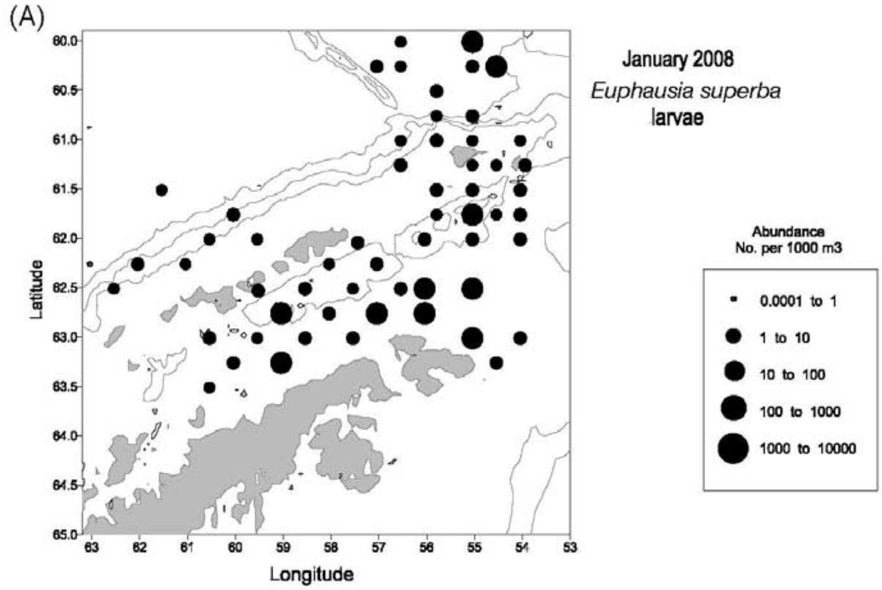


Figure 4.5. Length-frequency distribution and maturity stage composition of krill belonging to Clusters during (A) January and (B) February-March Survey D, 2008.



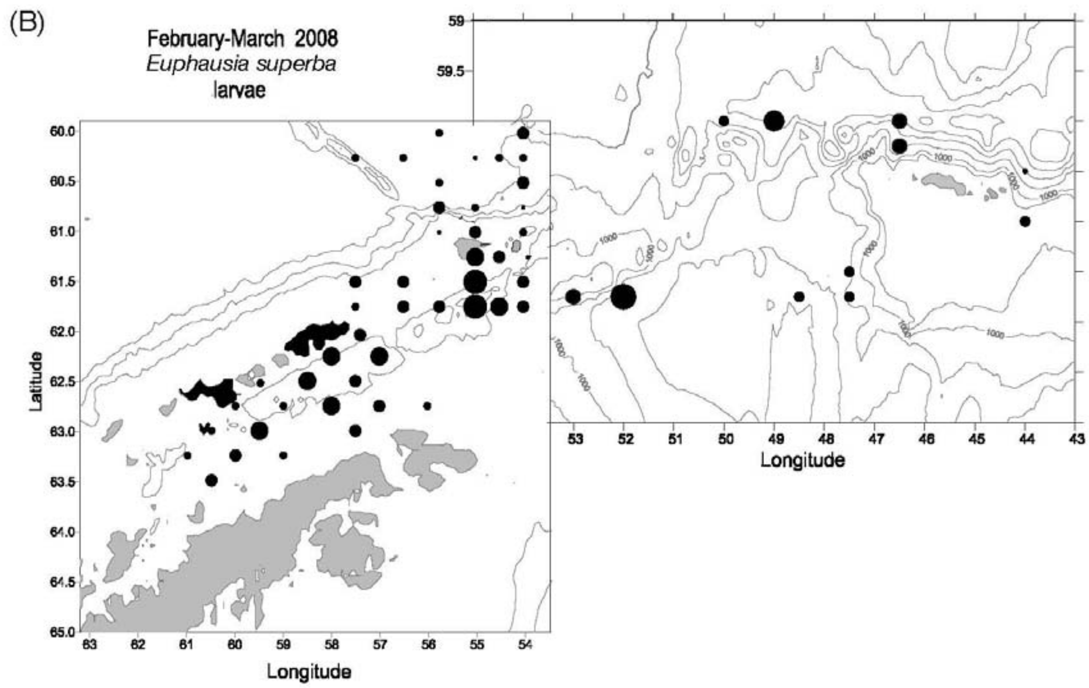
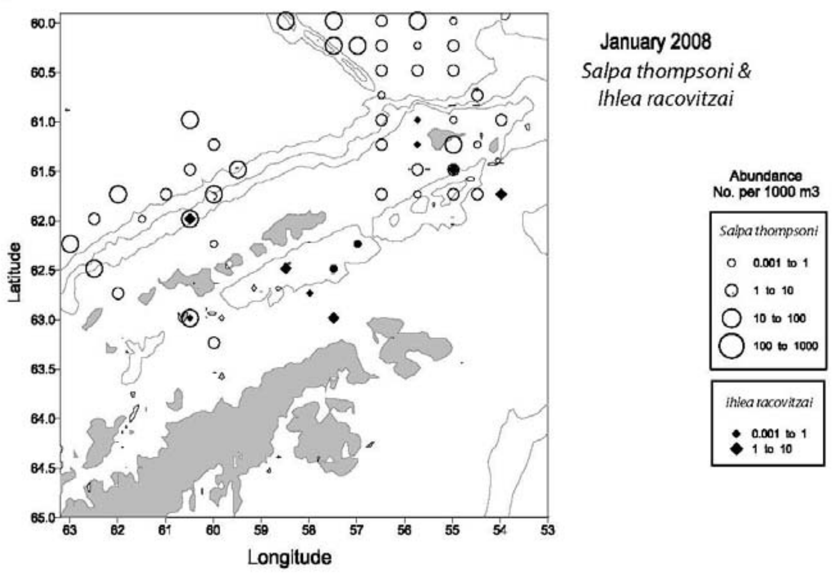


Figure 4.6. Distribution and abundance of larval krill during (A) January Survey A and (B) February-March Survey D, 2008.

(A)



(B)

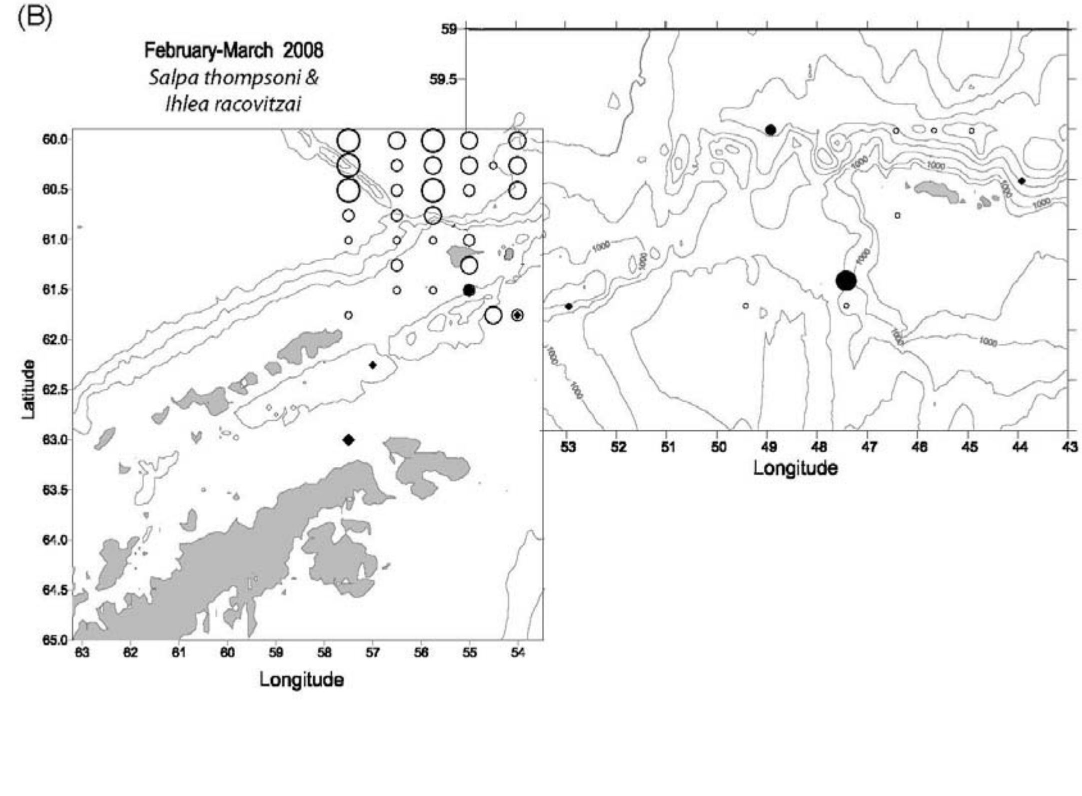


Figure 4.7. Distribution and abundance of *Salpa thompsoni* and *Ihlea racovitzai* during (A) January Survey A and (B) February-March Survey D, 2008.

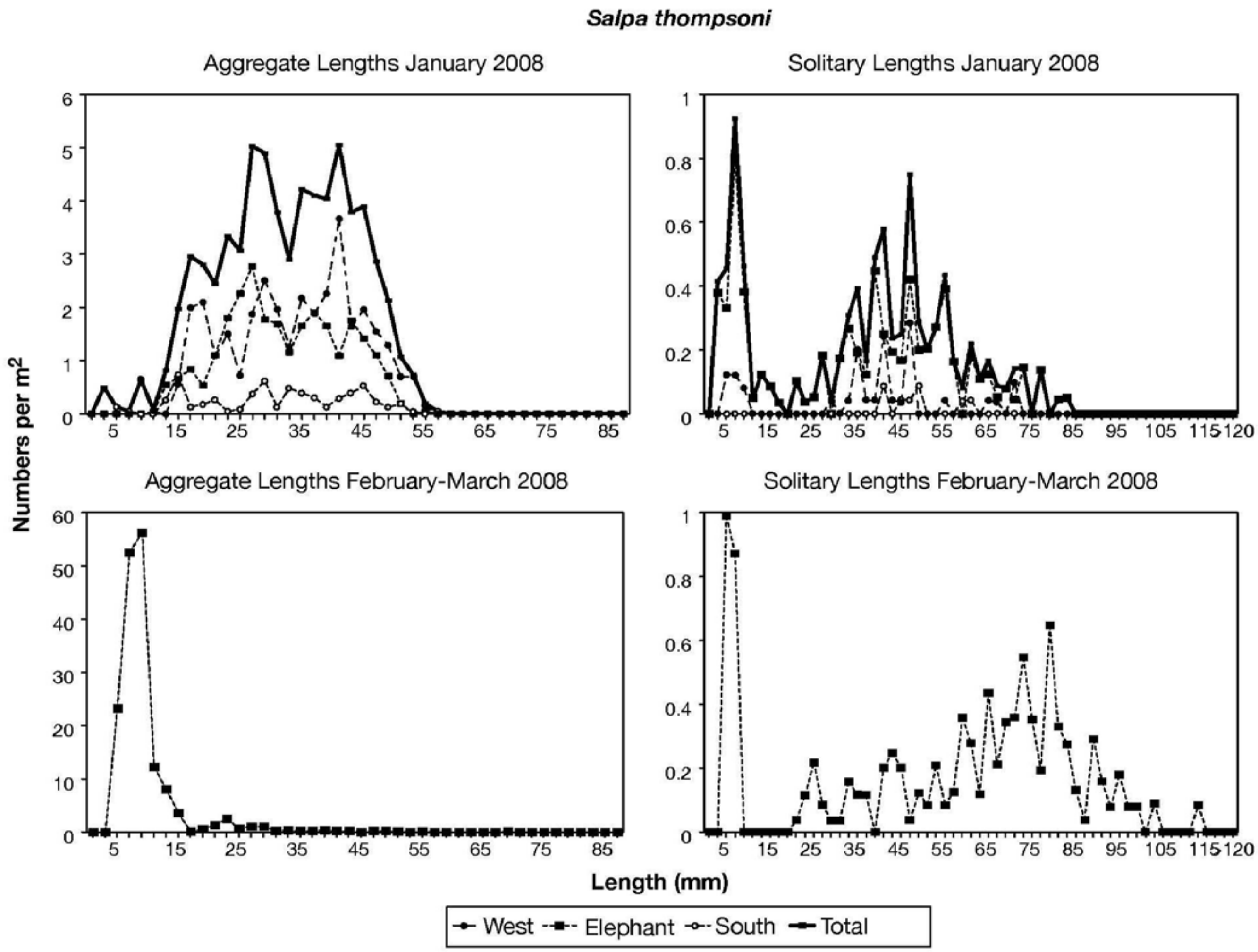
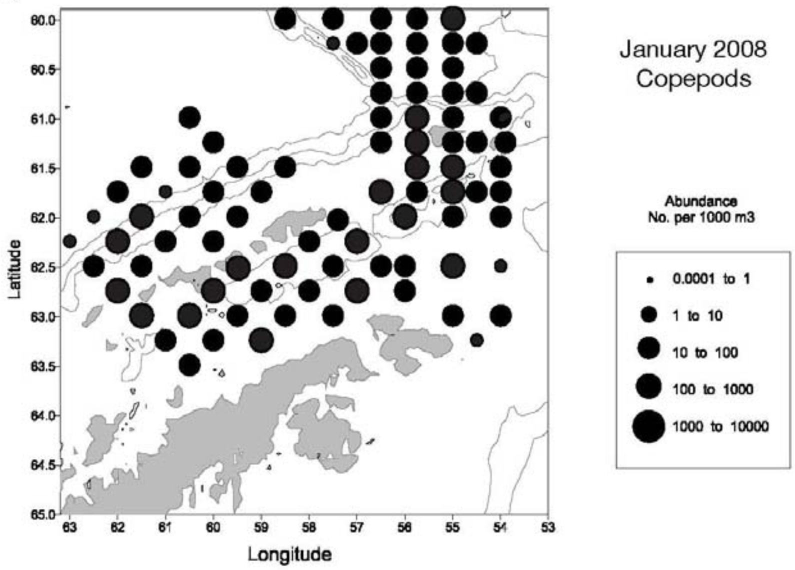


Figure 4.8. Length-frequency distributions of aggregate and solitary stage *Salpa thompsoni* during January and February-March, 2008.

(A)



(B)

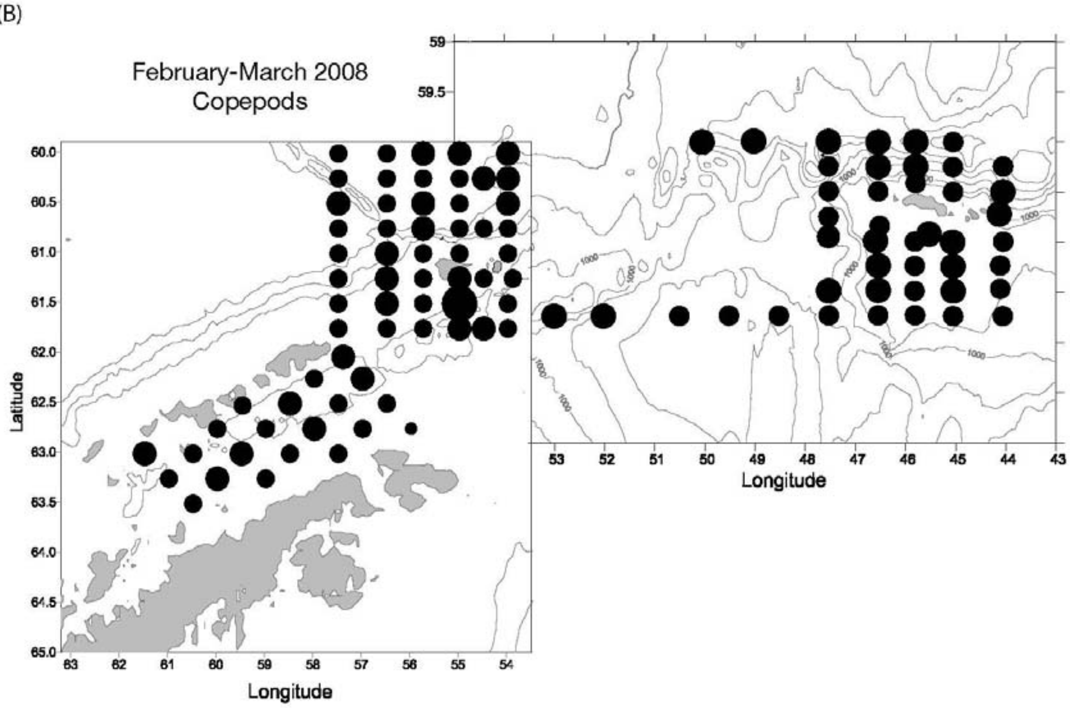


Figure 4.9. Distribution and abundance of total copepods (A) January Survey A and (B) February-March Survey D, 2008.

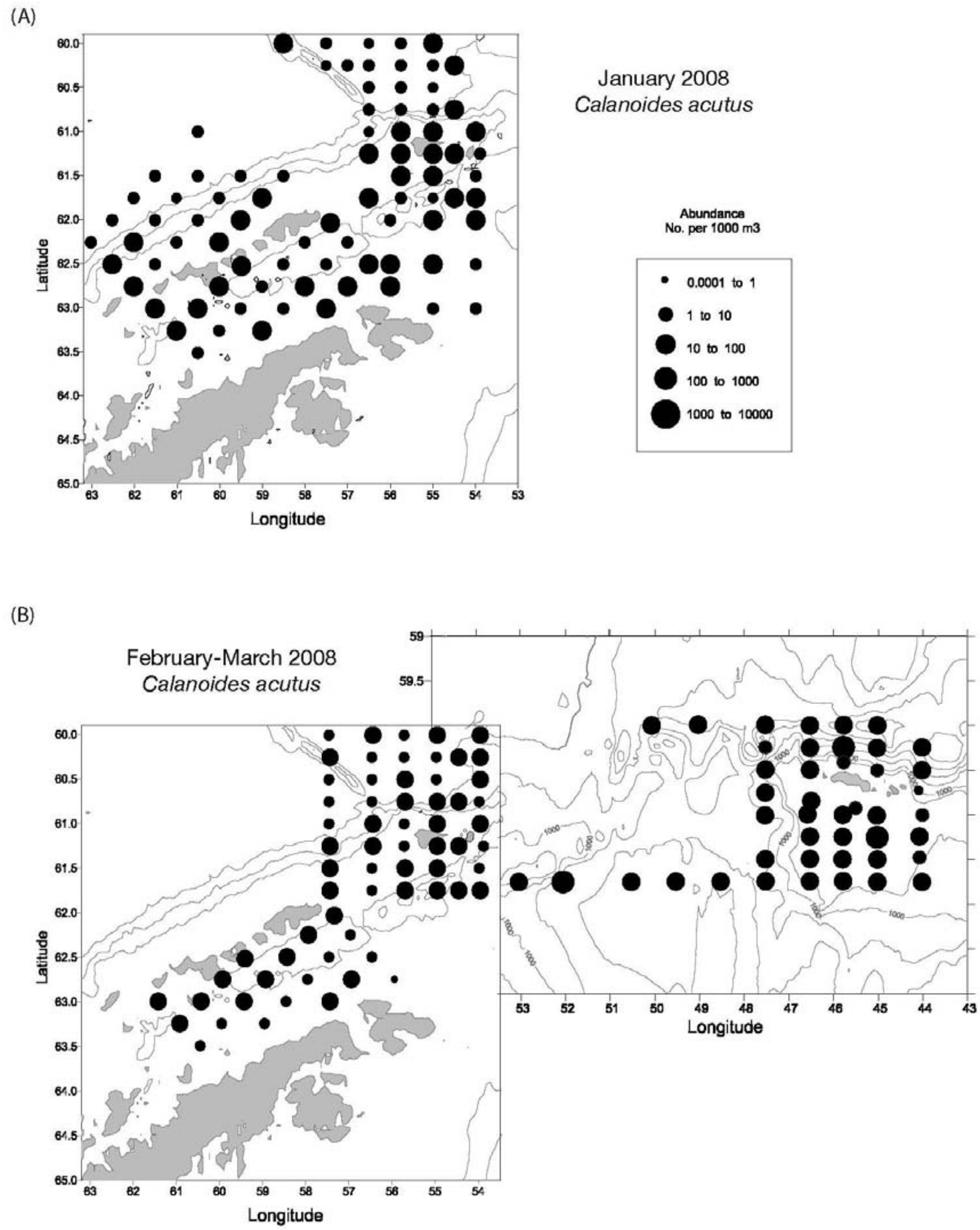
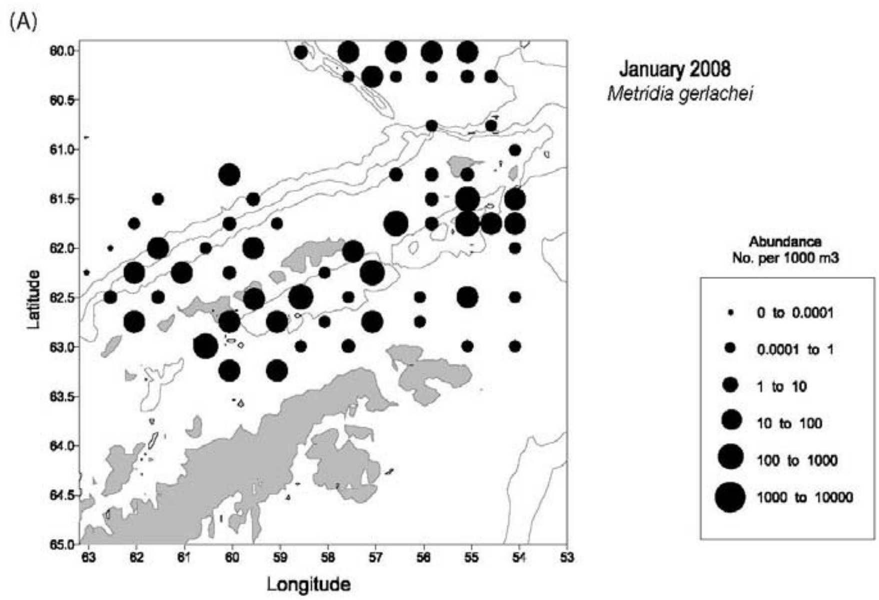


Figure 4.10. Distribution and abundance of *Metridia gerlachei* during (A) January Survey A and (B) February-March Survey D, 2008.



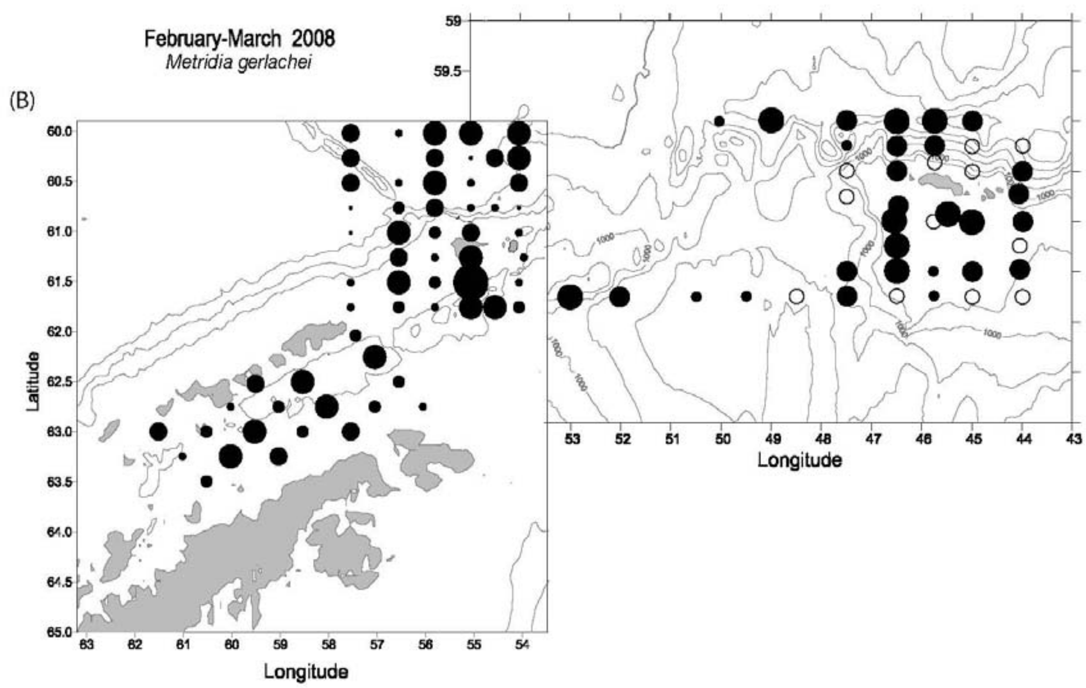
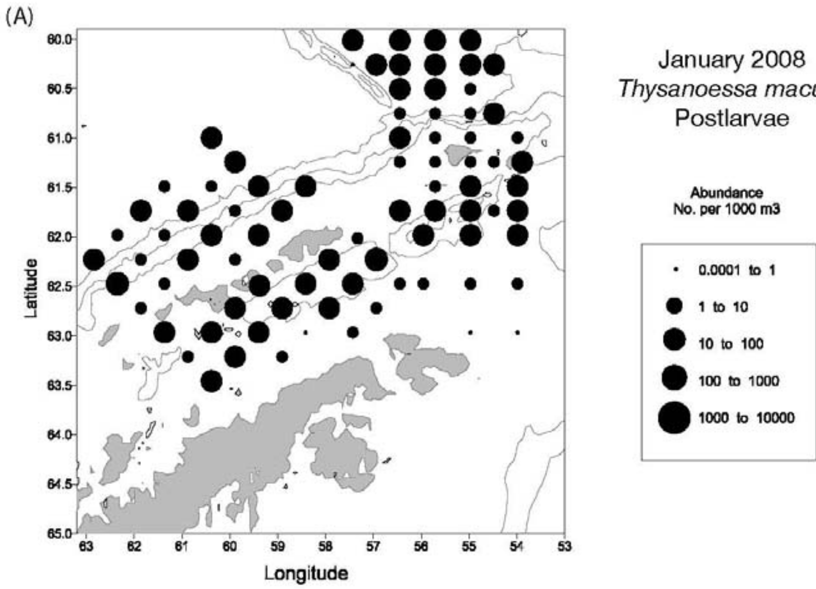


Figure 4.11. Distribution and abundance of *Calanoides acutus* during (A) January Survey A and (B) February-March Survey D, 2008.



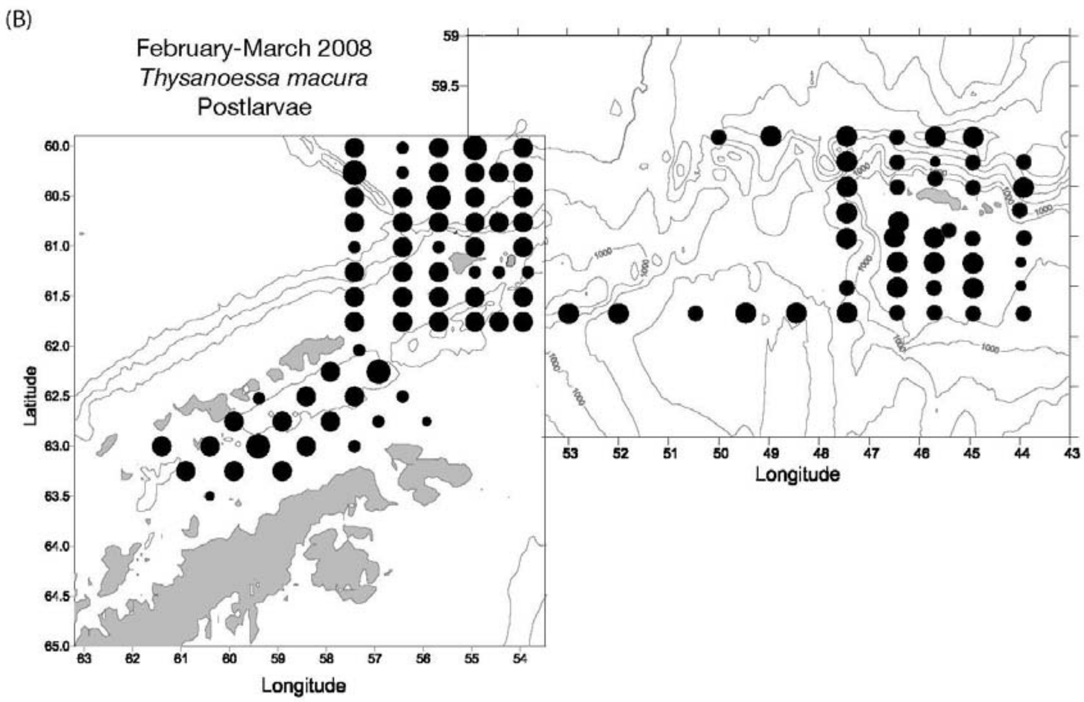
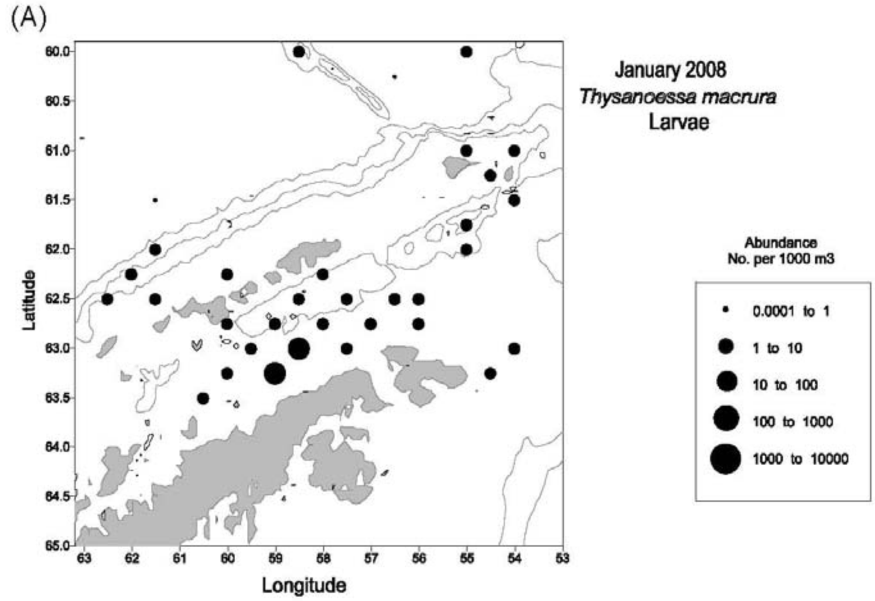


Figure 4.12. Distribution and abundance of postlarval *Thysanoessa macrura* during (A) January Survey A and (B) February-March Survey D, 2008.



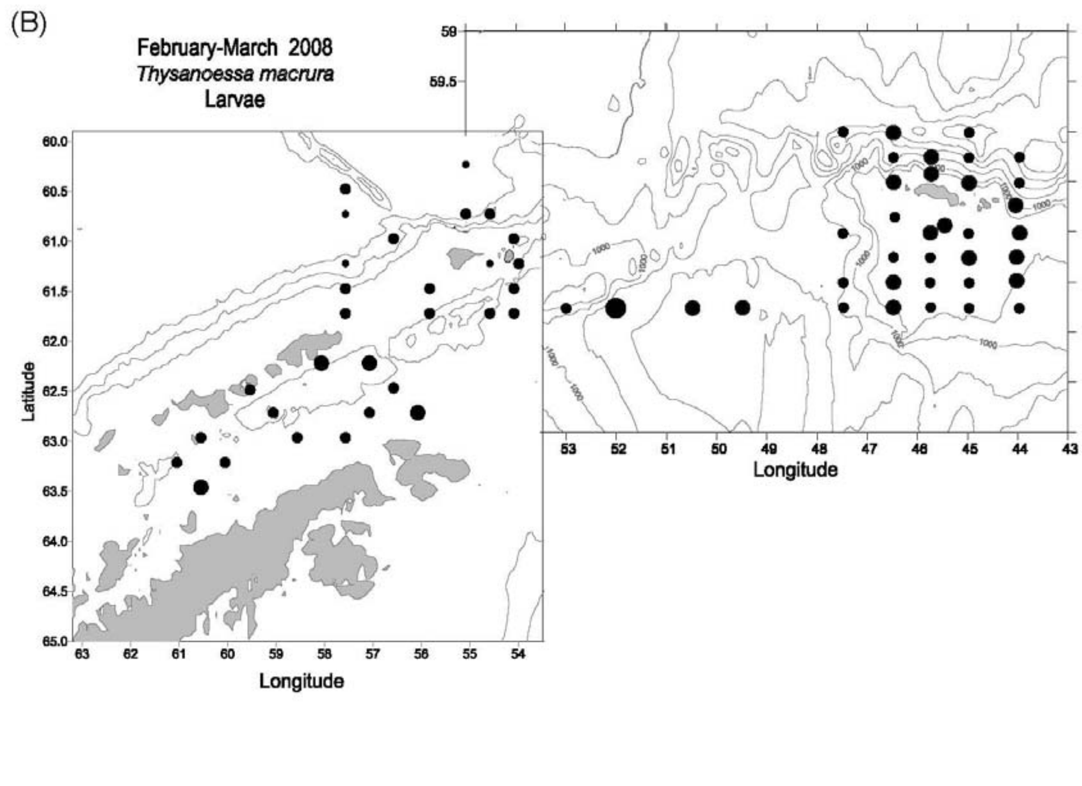


Figure 4.13. Distribution and abundance of larval *Thysanoessa macrura* during (A) January Survey A and (B) February-March Survey D, 2008.

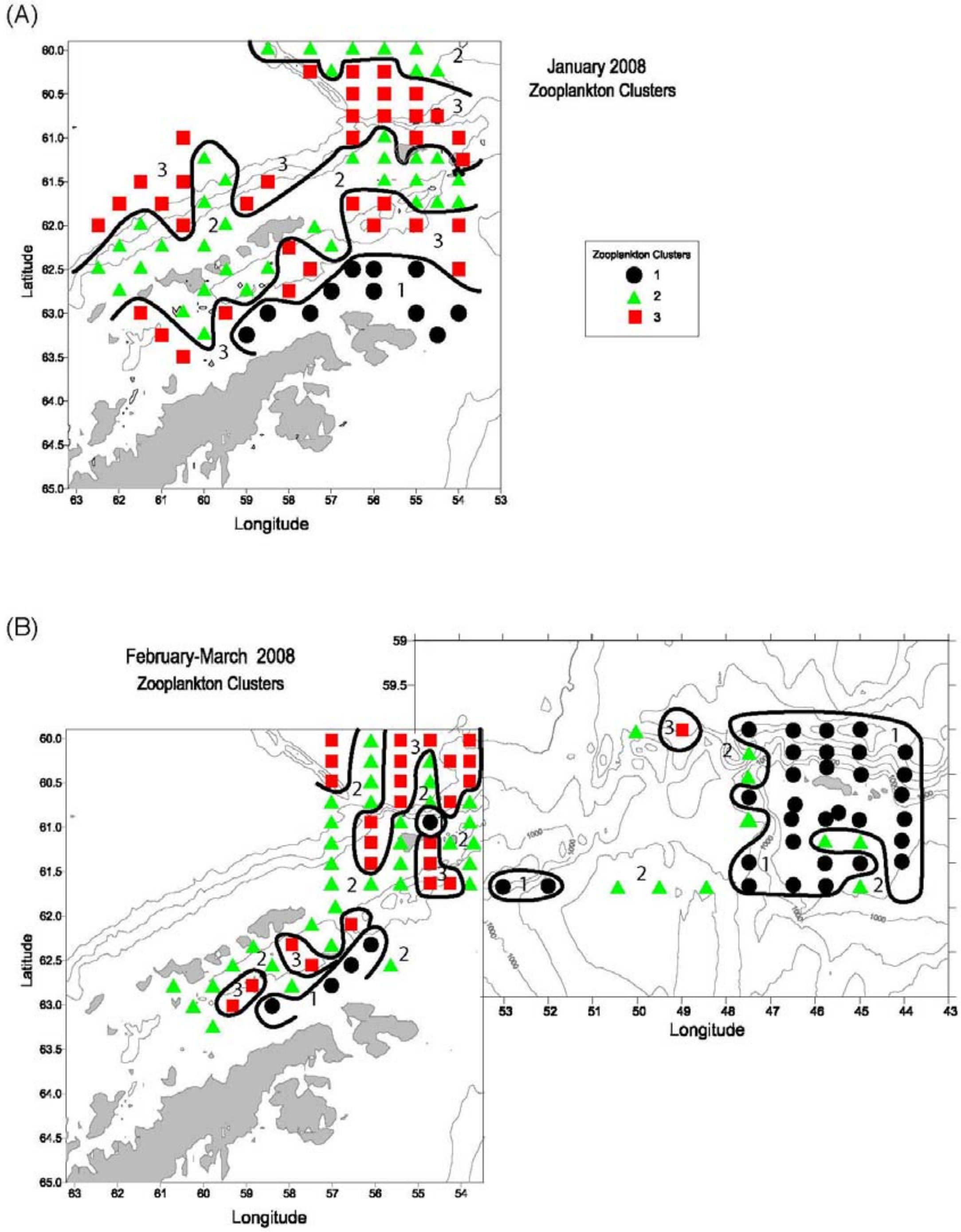


Figure 4.14. Distribution patterns of zooplankton taxa belonging to different station groupings corresponding to Clusters 1-3 (A) January Survey A and (B) February-March Survey D, 2008.

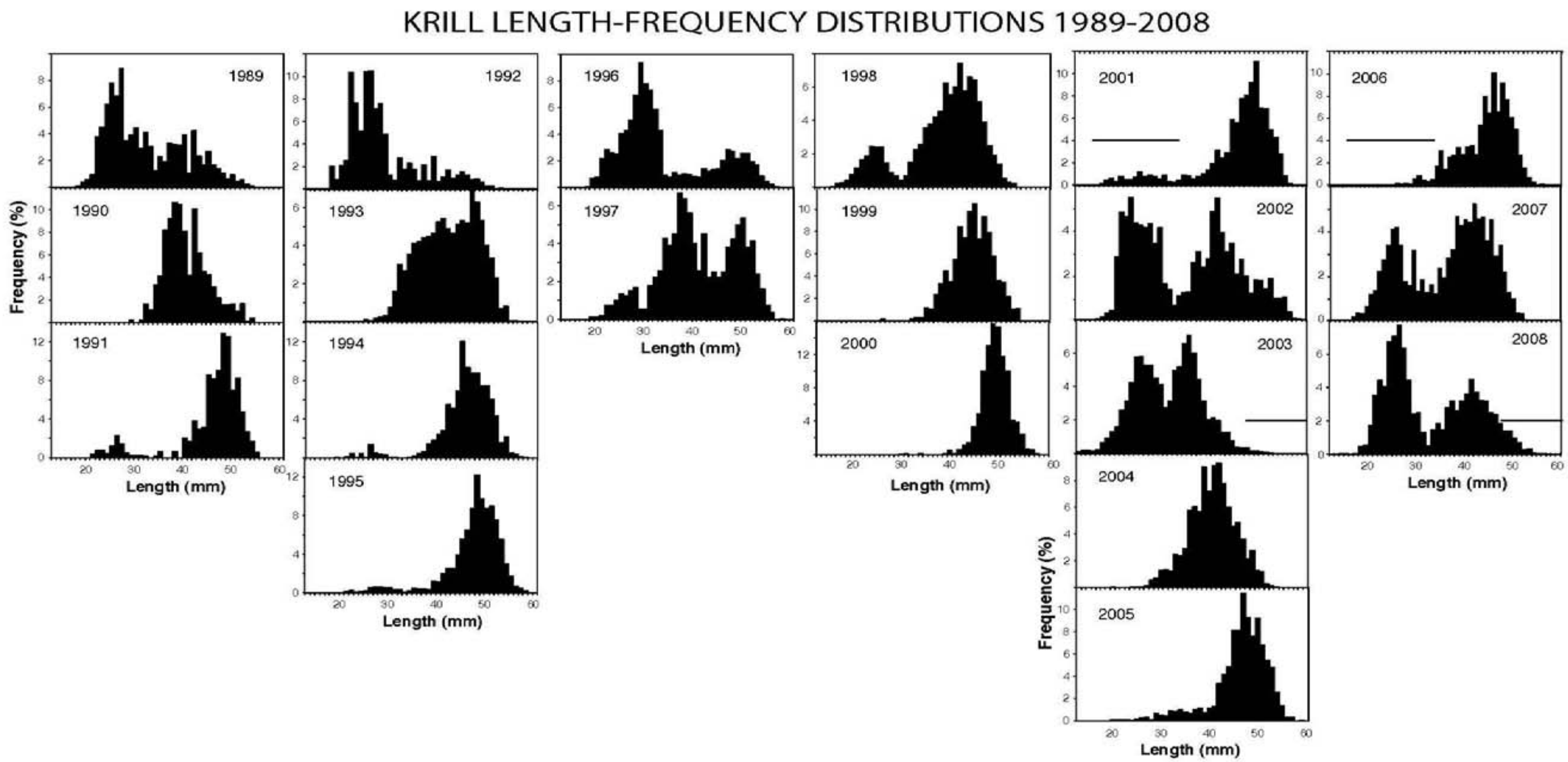


Figure 4.15. Krill length-frequency distributions represented in the Elephant Island Area during 1989-2008 showing temporal sequences of good and poor recruitment success. January-February surveys are used for all years except 2000. Horizontal lines indicate years when abundance of younger and older age classes might have been not adequately represented due to latitudinal movements relative to the survey area.

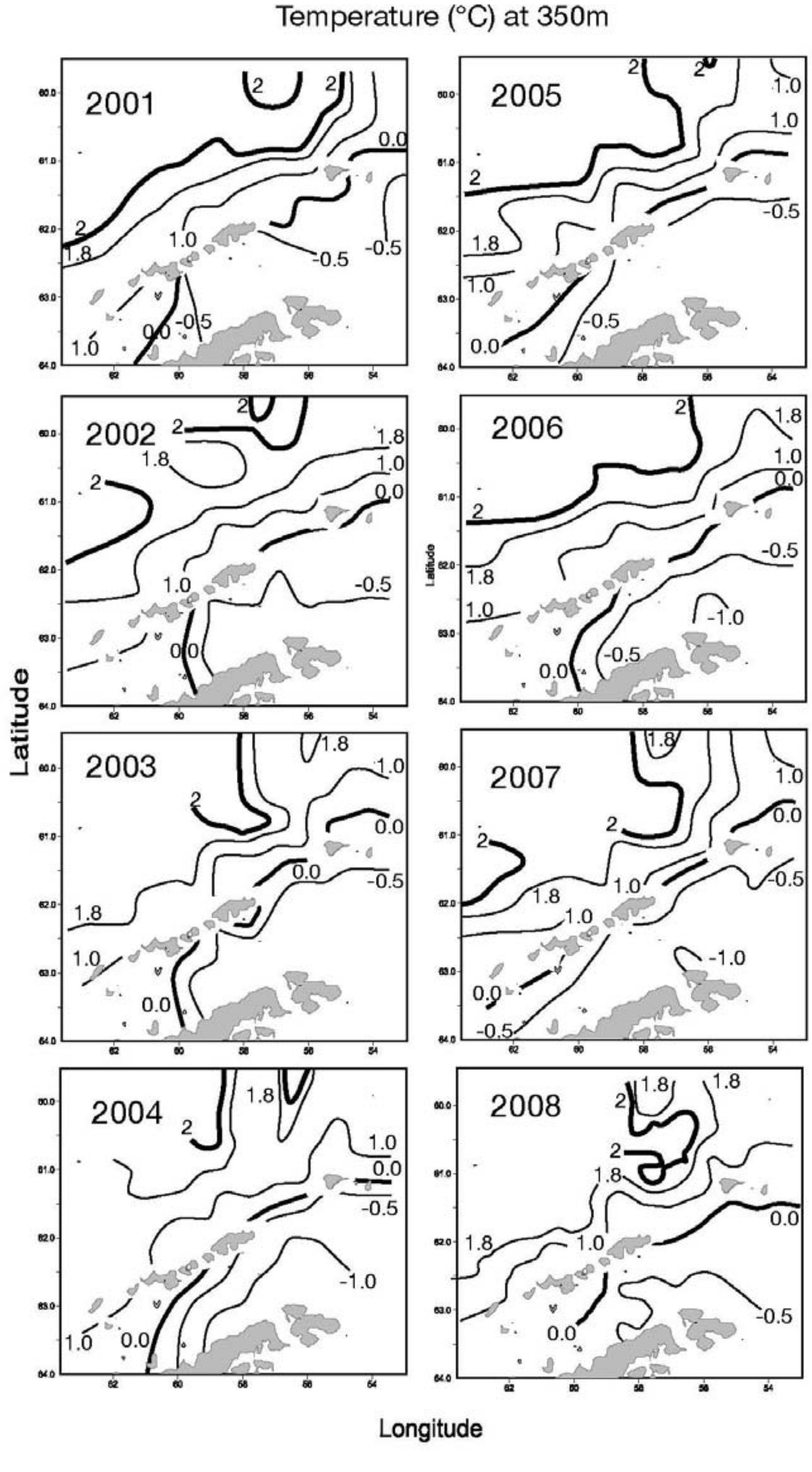


Figure 4.16. Temperature at 350m depth to demonstrate latitudinal movements of the ACC between 2001 and 2008.

5. Seabird Research at Cape Shirreff, Livingston Island, Antarctica, 2007-2008; submitted by Sarah E. Chisholm, Kevin W. Pietrzak, Aileen K. Miller and Wayne Z. Trivelpiece

5.1 Objectives:

The U.S. Antarctic Marine Living Resources (AMLR) program conducted its eleventh field season of land-based seabird research at the Cape Shirreff field camp on Livingston Island, Antarctica (62º 28'S, 60º 46'W), during the austral summer of 2007-08. Cape Shirreff is a Site of Special Scientific Interest and long-term monitoring of predator populations are conducted in support of US participation in the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR).

The objectives of the seabird research program for the 2007-08 season, as part of the long-term monitoring efforts agreed upon at CCAMLR (2004), were as follows:

1. To estimate chinstrap (*Pygoscelis antarctica)* and gentoo penguin (*P. papua)* breeding population size (Standard Method A3, CCAMLR 2004);
2. To band 500 chinstrap and 200 gentoo penguin chicks for demography studies (Std. Method A4, CCAMLR 2004);
3. To determine chinstrap penguin foraging trip duration during the chick rearing stage of the reproductive cycle (Std. Method A5, CCAMLR 2004);
4. To determine chinstrap and gentoo penguin breeding success (Std. Methods 6a.b&c, CCAMLR 2004);
5. To determine chinstrap and gentoo penguin chick weight at fledging (Std. Method 7c, CCAMLR 2004);
6. To determine chinstrap and gentoo penguin diet composition, meal size, and krill length/frequency distribution (Std. Methods 8a,b&c, CCAMLR 2004); and
7. To determine chinstrap and gentoo penguin breeding chronology (Std. Method 9, CCAMLR 2004).

5.2 Results:

5.2.1 Breeding biology studies:

The penguin rookery at Cape Shirreff consisted of 19 sub-colonies of gentoo and chinstrap penguins during the 2007-08 breeding season. We conducted nest censuses for gentoos on December 10, 2007 and for chinstraps on December 1, 2007, approximately 1 week after mean clutch initiation for each species. Mean clutch initiation for gentoo penguins was the latest observed in 11 years of study. A total of 610 gentoo penguin nests were counted. This is the lowest count observed in 11 years of study (Figure 1): 22% lower than the 2006-07 count and 19% lower than the previous 10-year mean. A total of 3,032 chinstrap penguin nests were counted, which was also the lowest count observed in 10 years of study (Figure 2): 33% lower than the 2006-07 count and 51% lower than the previous 10-year mean. This count represents the tenth continuous year of decline of the chinstrap penguin breeding population at Cape Shirreff. The low nesting counts for both species appeared to be, at least in part, a result of unusually deep snow cover and frequent snow storms around the time of egg-laying; some penguins may have forgone breeding due to the conditions, while other penguins' nests failed in few days after initiation and before censuses were conducted.

Chick censuses were conducted for gentoo penguins on February 19, 2008 and for chinstrap penguins on February 12, 2008, approximately one week after mean crèche for each species. The gentoo penguin count was 544 chicks. This count is 43% lower than the 2006-07 count and 45% lower than the previous

11-year mean (Figure 1). The chinstrap penguin count was 1135 chicks (Figure 2), which is 79% lower than the 2006-07 count and 84% lower than the previous 11-year mean.

Based on census data, overall gentoo penguin fledging success was 0.89 chicks/nest. This is 33% lower than the previous 10-year mean. Overall chinstrap penguins fledging success was 0.37 chicks/nest, which is 66% lower than the previous 10-year mean.

Reproductive success was also measured by following a sample of 50 pairs of breeding gentoo penguins and 100 pairs of breeding chinstrap penguins from clutch initiation through to crèche formation. Because chick mortality is typically low following crèche, these numbers also serve as an estimate of fledging success.

Based on data from our reproductive study, gentoo penguins fledged 0.56 chicks/nest and chinstrap penguins fledged 0.23 chicks/nest. This low reproductive success for both species is also likely explained by high snow cover and inclement weather during clutch initiation and incubation causing numerous nest failures: 54% of gentoo penguins and 75% of chinstrap penguin nests did not hatch any chicks.

Thirteen nests selected for the gentoo penguin reproductive study failed before one pair member was banded, making it impossible to measure the success of their second clutches. For this reason, an additional 13 gentoo penguin nests that initiated clutches later than average (and were presumably second clutches) were added to the study plots. Reproductive success at these nests was 1.0 chicks/nest.

Nests of known-age penguins that initiated clutches were also followed to crèche. Fourteen known-age gentoo penguin nests (by definition, one member of the pair is of known age) fledged 0.36 chicks/nest. Eighteen known-age chinstrap penguin nests fledged 0.11 chicks/nest.

A sample of 100 gentoo and 250 chinstrap penguin chicks was banded for future demographic studies. This is half the number of chicks normally banded each year at Cape Shirreff: fewer chicks were banded due to the unusually low number of chicks in the colonies. The banded chicks that survive and return to the colony as adults will be observed for age-specific survival and reproductive success.

Fledging weights were collected from gentoo and chinstrap penguin chicks as a measure of chick condition. Gentoo penguin chicks are still provisioned by their parents after they begin making trips to sea, so it is not possible to obtain definitive fledging weights by catching and weighing chicks prior to departure. Alternatively, gentoo penguin chicks are weighed 85 days after their mean clutch initiation date, which is approximately the age when other *Pygoscelis* chicks fledge. A sample of gentoo penguin chicks was weighed on February 24, 2008 and had an average mass of 4,242g (n = 128; S.D. = 805). This is comparable to the previous 10-year mean. Chinstrap penguin fledglings were caught on the beaches just before fledging - between February 20 and 29, 2008 - and had an average mass of 3,053g (n = 115; S.D. = 319). This is slightly lower (3%) than the previous 11-year mean.

5.2.2 Foraging ecology studies:

Diet samples were collected from 20 gentoo and 40 chinstrap penguins between January 11 and February 9, 2008. Adults were captured at nest sites upon their return from foraging trips, to assure they were feeding chicks. The total stomach contents were collected using the wet-offloading technique (Wilson 1984). Antarctic krill (*Euphausia superba*) was present in all but one sample and comprised the majority of diet in 90% of samples. Fish was the next largest component and squid and other marine invertebrates represented <1% of penguin diets.

In the 2007-08 season, 100% of the gentoo penguin diet samples contained evidence of fish, while in the previous 10 years of study only 73% of gentoo diet samples contained evidence of fish. This is the second consecutive year of our study in which all gentoo penguin diet samples contained evidence of fish. In contrast, 32% of chinstrap penguin diet samples contained evidence of fish which is comparable to the previous 10-year average of 30%. Fish represented 27% of the gentoo penguin diet by mass and <1% of the chinstrap penguin diet by mass.

A sub-sample of 50 individual Antarctic krill from each diet sample were measured and sexed to determine length and sex frequency distributions of the krill selected by foraging penguins. Krill in gentoo penguin samples were larger on average (46mm) than krill in chinstrap penguin samples (41mm) (Figure 3). Penguin diets consisted of 18% juvenile krill (those less than 36mm in length), 42% male kirll and 40% female krill (Figure 4).

The average chick meal mass for chinstrap penguins was 565g; this is 7% lower than the previous 10-year mean of 609g. The average age of chinstrap chicks from which diet samples were taken was 3.4 weeks, less than the previous 10-year mean of 3.8 weeks. The ratio of fresh to digested portions in the chinstrap penguin's diet samples was comparable to the previous nine seasons. We only collected the fresh portion of diet samples from gentoo penguins, so chick meal mass was not evaluated.

Radio transmitters were deployed on 18 adult chinstrap penguins during the chick rearing phase in order to determine their foraging trip durations. Colony attendance was logged between January 6, 2008 and March 3, 2008 using a remote receiver and data collection computer. Mean foraging trip duration was 12.4 hours (n = 18; S.D. = 2.1). This was longer than the average foraging trip duration of 10.95 hours observed in 2006-07.

Gentoo and chinstrap penguins were also instrumented with satellite transmitters (PTTs) to provide geographic data on adult foraging locations during the chick rearing period. Sixteen PTTs were deployed on eight gentoo penguins in late January and on eight chinstrap penguins in early January during the brooding phase for each species. Fifteen PTTs were deployed on seven gentoo penguins and eight chinstrap penguins in mid February during the crèche phase for both species. PTT data are awaiting analysis.

Time-depth recorders (TDRs) were also attached to chinstrap and gentoo penguins to collect penguin diving behavior data during the chick-rearing period. The first round of TDRs was deployed on eight gentoo penguins in late January and on 11 chinstrap penguins in early-to-mid January while these adults were brooding chicks. A second round of TDRs was deployed on seven gentoo penguins and seven chinstrap penguins in mid February during the crèche phase when nests were unattended because both parents forage simultaneously. Dive data are awaiting analysis.

5.2.3 Other seabirds

The breeding success of all skuas at Cape Shirreff and nearby Punta Oeste was followed. There were 24 skua pairs holding territories, all of which were brown skuas (*Catharacta lonnbergi*) with the exception of one pair that are likely hybrid, brown-South Polar skuas (*C. maccormicki*). Clutches were initiated by 19 pairs and overall fledging success was 0.26 fledglings/pair. This is the lowest fledging success observed in 11 years of study; it is 64% lower than the previous 10-year average.

The reproductive performance of kelp gulls (*Larus dominicanus*) nesting on Cape Shirreff was also followed throughout the season. Thirty two nests were initiated and overall fledging success was 0.56 fledglings/pair.

5.3 Conclusions:

Our eleventh complete season of seabird research at Cape Shirreff allowed us to assess trends in penguin population size, as well as inter-annual variation in reproductive success, diet and foraging behavior.

Breeding population counts and reproductive success of both gentoo and chinstrap penguins were significantly below the 10-year average. These parameters were negatively affected by poor nesting conditions and inclement weather during clutch initiation and incubation. High snow cover inhibited the construction of adequate nest bowls and high winds and snow drift resulted in the failure of many nests before nest censuses were conducted and in the weeks following censuses. This explains the low population counts and poor reproductive success. Fledging weights of both species were comparable to the previous 10-year average.

Diet composition of both species was comparable to previous seasons; all gentoo penguin samples contained fish and chinstrap penguin samples contained a relatively high proportion of juvenile krill. Total chick meal mass of chinstrap penguins was slightly lower than the previous 10-year mean but it is unclear if this can be explained by the fact that samples were collected from adults with younger chicks. The mean foraging trip duration of chinstrap penguins was slightly longer than observed in 2006-07. The foraging location and diving behavior data collected with PTTs and TDRs should assist in interpreting the foraging trip data.

5.4 Acknowledgements:

We would like to sincerely thank Gitte McDonald, Scott Freeman and Russell Haner for their invaluable assistance and companionship in the field. We would also like to thank the Chilean research team of Daniel Torres, Pilár Diaz, Susan Aburto and Verónica Villelobos for their assistance in the field and for their camaraderie. We are grateful to the crew of the NSF research vessel *Laurence M. Gould* for our smooth transit to Cape Shirreff and for their help with camp opening, and to the crew of the AMLR chartered research vessel *Yuzhmorgeologiya* for their efforts in resupplying our camp and for providing transit back to Punta Arenas, Chile.

5.5 References:

CCAMLR (2004) CCAMLR Ecosystem Monitoring Program: standard methods. CCAMLR, Hobart

Wilson RP (1984) An improved stomach pump for penguins and other seabirds. J Field Ornithol 55:109–112

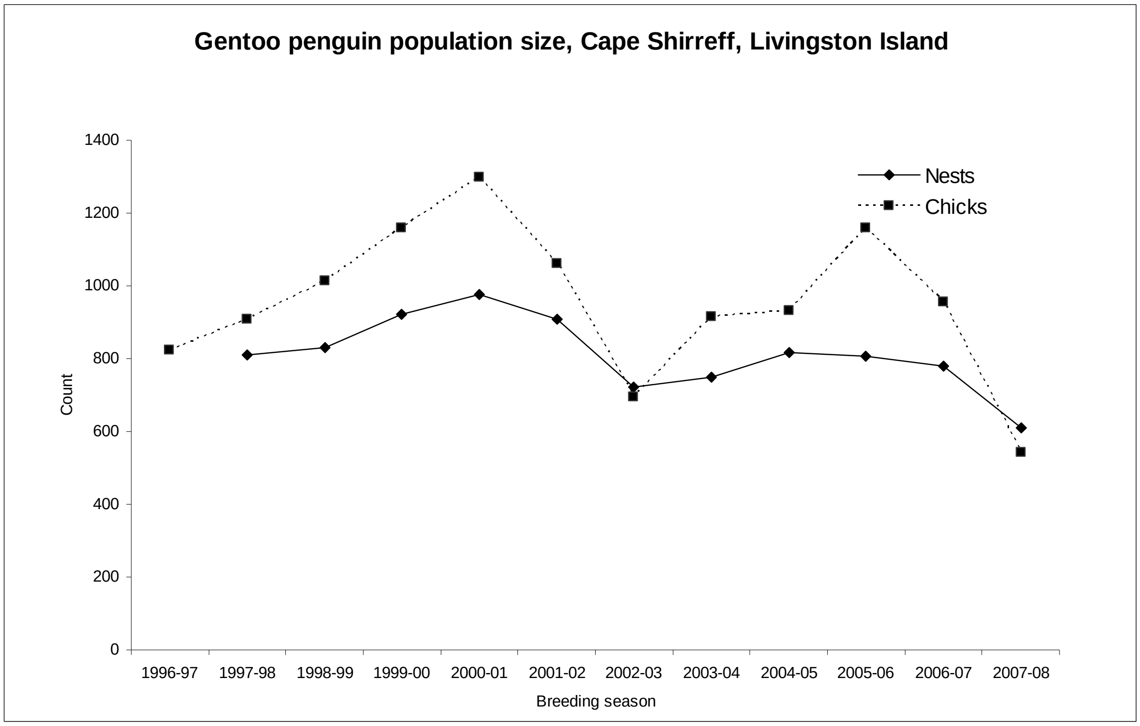


Figure 5.1. Gentoo penguin population size at Cape Shirreff, Livingston Island, Antarctica, 1996-97 to 2007-08.

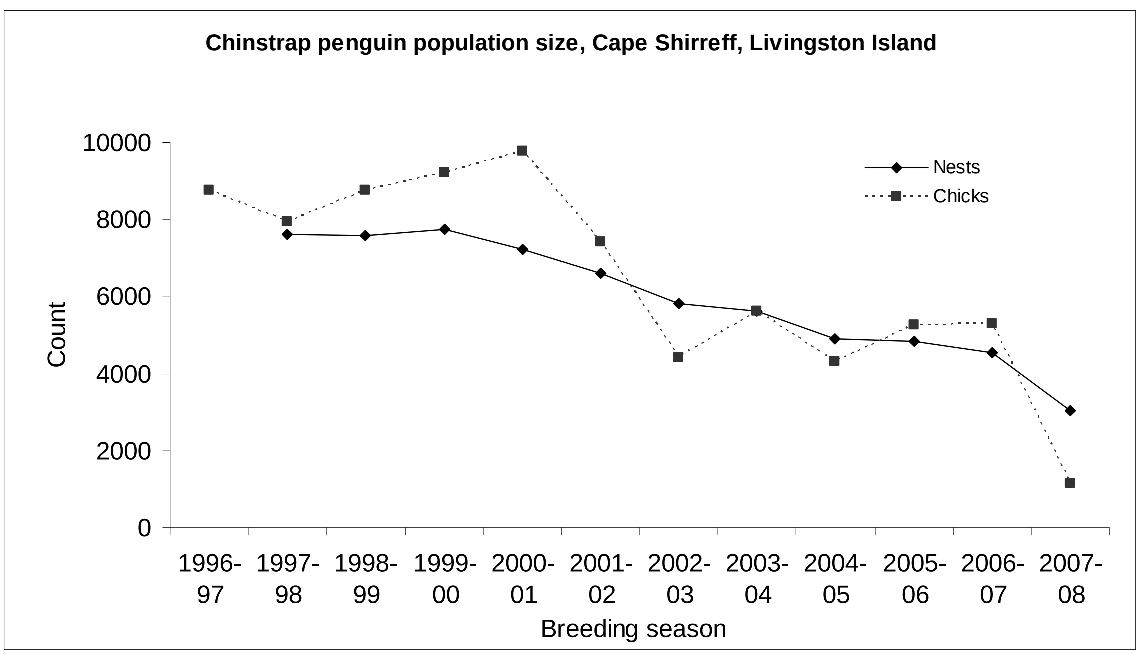


Figure 5.2. Chinstrap penguin population size at Cape Shirreff, Livingston Island, Antarctica, 1996-97 to 2007-08.

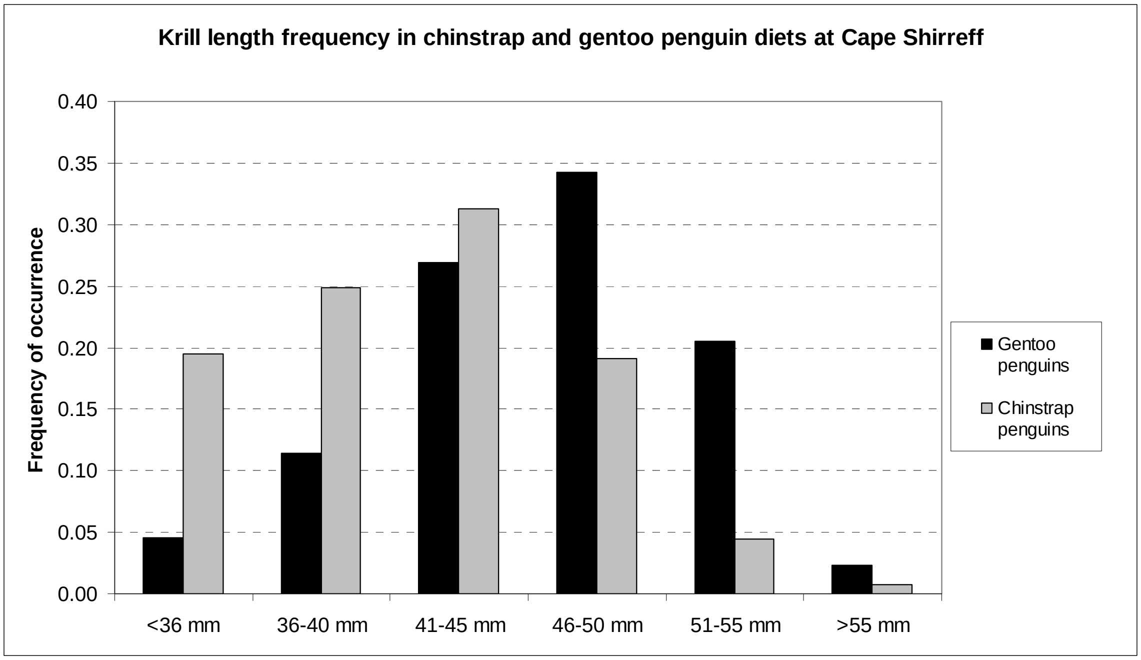


Figure 5.3. Krill length frequency distribution in gentoo and chinstrap penguin diet samples at Cape Shirreff, Livingston Island, Antarctica, 2007-08.

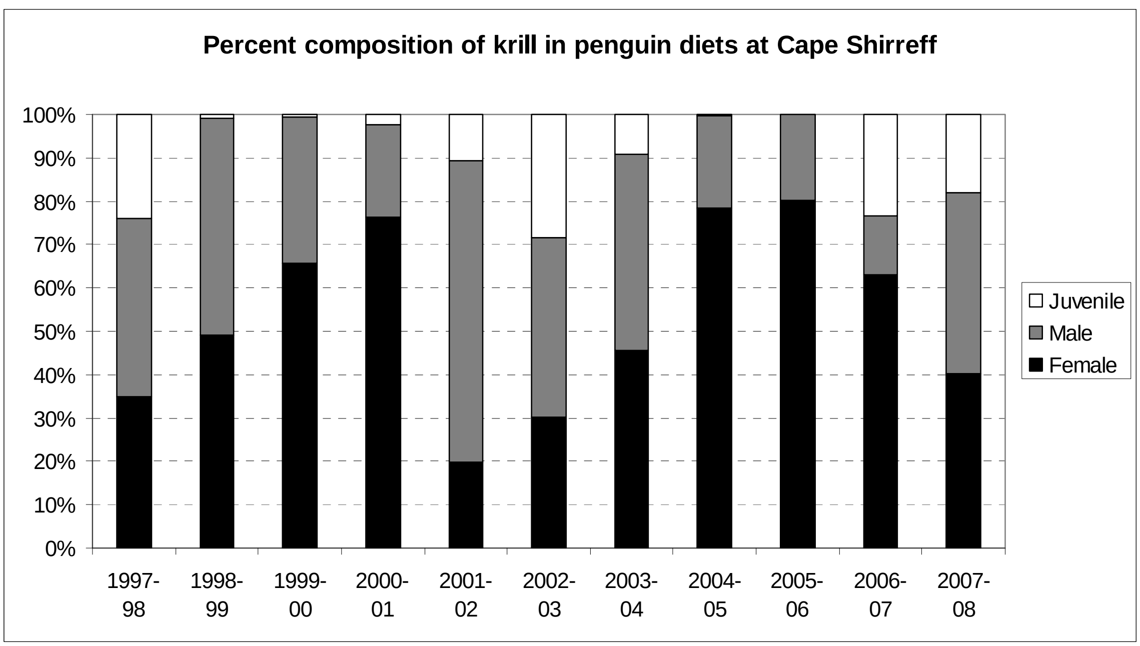


Figure 5.4. Percent composition of Antarctic krill (*Euphausia superba*) in gentoo and chinstrap penguin diet samples at Cape Shirreff, Livingston Island, Antarctica, 1997-98 to 2007-08.

6. Pinniped research at Cape Shirreff, Livingston Island, Antarctica, 2007/08; submitted by Michael E. Goebel, Birgitte I. McDonald, Scott Freeman, Russell G. Haner, Natalie B. Spear, and Stephanie N. Sexton.

6.1 Objectives: As upper trophic level predators, pinnipeds are a conspicuous component of the marine ecosystem around the South Shetland Islands. They respond to spatio-temporal changes in physical and biological oceanography and are directly dependent upon availability of krill (*Euphausia superba*) for maintenance, growth, and reproduction during the austral summer. Because of their current numbers and their pre-exploitation biomass in the Antarctic Peninsula region and Scotia Sea, Antarctic fur seals are recognized to be an important "krill-dependent" upper trophic level predator. The general objectives for U.S. AMLR pinniped research at Cape Shirreff (62^{o}28'S, 60^{o}46'W) are to monitor population demography and trends, reproductive success, and foraging ecology of pinnipeds throughout the summer months. The Antarctic fur seal, *Arctocephalus gazella*, is the most abundant pinniped at Cape Shirreff; our studies are focused to a large degree on the foraging ecology, diving behavior, foraging range, energetics, diet, and reproductive success of this species.

The 2007/08 field season began with the arrival at Cape Shirreff of a five person field team via the R/V *Laurence M. Gould* on 7 November 2007. Research activities were initiated soon after and continued until closure of the camp on 8 March 2008. Our specific research objectives for the 2007/08 field season were to:

A. Monitor Antarctic fur seal female attendance behavior (time at sea foraging and time ashore attending a pup);
B. Monitor pup growth in cooperation with Chilean researchers by collecting mass measurements from a random sample of 100 fur seal pups every two weeks throughout the research period beginning 30 days after the median date of births;
C. Document fur seal pup production at designated rookeries on Cape Shirreff and assist, when necessary, Chilean colleagues in censuses of fur seal pups for the entire Cape and the San Telmo Islands;
D. Collect and analyze fur seal scat contents on a weekly basis for diet studies;
E. Collect a milk sample at each adult female fur seal capture for fatty acid signature analysis for diet studies;
F. Deploy time-depth recorders on adult female fur seals for diving studies;
G. Record at-sea foraging locations for adult female fur seals using GPS or ARGOS satellite-linked transmitters (with most deployments coinciding with the U.S.-AMLR Oceanographic Survey cruises);
H. Tag 500 fur seal pups for future demographic studies;
I. Re-sight animals tagged as pups in previous years for population demography studies;
J. Monitor survival and natality of the tagged adult female population of fur seals;
K. Extract a lower post-canine tooth from tagged adult female fur seals for aging studies;
L. Deploy a weather station for continuous recording of wind speed, wind direction, ambient temperature, humidity and barometric pressure during the study period;
M. Record any pinnipeds carrying marine debris (i.e., entanglement);
N. Record any other tagged pinnipeds observed on Cape Shirreff;
O. Capture and instrument Leopard seals for studies of top-down control of fur seal and penguin populations; and
P. Conduct an archipelago-wide census of fur seal pup production.

6.2 Methods, Accomplishments, and Results (by objective):

A. Female Fur Seal Attendance Behavior: Lactation in otariid females is characterized by a cyclical series of trips to sea and visits to shore to suckle their offspring. The sequential sea/shore cycles are commonly referred to as attendance behavior. Measuring changes in attendance behavior (especially the duration of trips to sea) is one of the standard indicators of a change in the foraging environment and availability of prey resources. Generally, the shorter the duration of trips to sea, the more resources a female can deliver to her pup during the period from birth to weaning.

We instrumented 28 lactating females from 3-14 December 2007. The study was conducted according to CCAMLR protocol (CCAMLR Standard Method C1.2 Procedure A) using VHF radio transmitters (Advanced Telemetry Systems, Inc., Model 7PN with a pulse rate of 40ppm). Standard Method C1.2 calls for monitoring of trip durations for the first six trips to sea. All females were instrumented 0-1 day post-partum (determined by the presence of a newborn with an umbilicus) and were left undisturbed for at least their first six trips to sea. Pups were captured at the same time as their mothers, and were weighed, measured, and marked with an identifying bleach mark. The general health and condition of the pups was monitored throughout the study by making daily visual observations. Presence or absence on shore was monitored for each female every 30 minutes for 30 seconds for the first six trips to sea using a remote VHF receiving station with an automated data collection and storage device. Data were downloaded weekly. Daily visual observations of instrumented females were conducted to validate automated data collection and to confirm proper functioning of the remote system.

The first female in our study to begin her foraging cycles did so on 9 December. All females had completed six trips to sea by 21 January. One female lost her pup before completion of six trips to sea.

The mean trip duration for the combined first six trips to sea was 3.71 days (±0.17, $N_{Females}$=27, N_{Trips}=162, range: 0.71-8.33; Figure 6.1). The mean duration for the first six non-perinatal visits was 1.35 days (±0.07, $N_{Females}$=27, N_{Visits}=159, range: 0.37-4.77) (Figure 6.1).

We use female post-partum mass as an index of condition at the start of the breeding season. The mean post-partum mass this year was 50.6kg (±1.00, N=29; Figure 6.2a). The mass-to-length ratio (arc-sin transformed), was 400.0g/cm (±6.70, N=29; Figure 6.2b).

B. Fur Seal Pup Growth: Measurement of fur seal pup growth was a collaborative effort between the U.S. research team and Chilean researchers. Pup weights and lengths were measured every two weeks beginning 30 days after the median date of pupping (6 Dec 2007) and ending 19 February (four bi-weekly samples; collection dates: 4 Jan, 19 Jan, 3 Feb, and 19 Feb). Data were collected as directed in CCAMLR Standard Method C2.2 Procedure B. The results are submitted to CCAMLR by Chilean researchers.

C. Fur Seal Pup Production: Fur seal pups (live and dead) and females were counted by U.S. researchers at four main breeding beaches on the east side of Cape Shirreff, which compose the U.S.-AMLR study site. Censuses for live pups were conducted every day from 5-12 December 2007 and from 25-31 December 2007. Dead pups were counted once a day from 17 Nov 2007-10 Jan 2008. The estimated total pups born (live plus cumulative dead) for the combined four beaches in 2007/08 was 1809 (±6.3) (Figure 6.3). The median date of parturition was 6 December (since 1997/98, the median date of parturition has varied by five days: 6-10 Dec).

Neonate mortality was similar to last year (4.2 % vs. 4.8%). Neonate mortality is defined as pup mortality occurring from the start of the breeding season (~15 Nov) until up to one month after the median date of pupping (6 January) and before the start of Leopard seal predation (~mid-January). It is measured by recording the number of new pup carcasses on the census beaches at each count and calculating a cumulative mortality every other day (i.e. at each census) from the start of births (17 November) until the last of pupping (~10 January). The long-term average (based on nine years of data, 1998-2007), is 4.5% ±0.60.

Our measures of neonate mortality extend only to the end of pupping (10 January). In most years neonate mortality experiences a peak during the perinatal period, or soon after females begin their trips to sea. Another peak in pup mortality occurs later, when young inexperienced pups enter the water for the first time around one month of age and become vulnerable to leopard seal predation. Since remains are rare, evidence of this type of mortality is more difficult to quantify. Leopard seal predation is significant and may be a factor controlling recovery of South Shetland populations of fur seals (Boveng *et al*., 1998). To estimate the extent of leopard seal predation on neonates we calculated the loss of pups from our tagged population of females. We assumed that once pups survived to one month of age that their disappearance was due to leopard seal predation. We included only females whose pup status could be confirmed, excluding female/pup pairs whose status was uncertain. Our estimate of pup mortality due to leopard seal predation, calculated 23 February - 79 days after the median date of pupping - was based on daily tag resights of adult females. By that date, 56.5% of pups were lost to leopard seals. Last year by 13 February 40.8% of pups were lost to predation.

D. Diet Studies: Information on fur seal diet was collected using three different sampling methods: collection of scats, enemas, and fatty acid signature analysis of milk. In addition to scats and enemas, an occasional regurgitation is found in female suckling areas. Regurgitations often provide whole prey that is only minimally digested. Scats are collected from around suckling sites of females or from captured animals that defecate while captive. All females that are captured to remove a time-depth recorder or satellite-linked transmitter (PTT) are given an enema to collect fecal material containing dietary information. In addition to diet information from captive animals, ten scats were collected from female suckling sites every week beginning 20 December. The weekly scat samples are collected by systematically walking transects of female suckling areas and collecting any fresh scats within a short range of the observer. This method prevents any bias associated with the difference in visibility between krill laden scats, which are bright pink, and fish laden scats, which are gray to brown and blend in with the substrate more easily.
In total, we collected and processed 110 scats from 20 December 2007-2 March 2008. Diet samples that could not be processed within 24 hours of collection were frozen. All samples were processed by 4 March. Up to 25 krill carapaces were measured from each sample that contained krill. Otoliths were sorted, dried, identified to species. The number of squid beaks were counted and preserved in 70% alcohol for later identification. A total of 2,477 krill carapaces were measured. Most scats, 97.3% (107/110) of those collected, contained krill. In addition, 2,864 otoliths were collected from 43.6% of the scats collected. Most (92.4%, 2647 otoliths) were from three species of myctophid fish (*Electrona antarctica*, n=791; *E. carlsbergi*, n=442 and *Gymnoscopelus nicholsi*, n=1414; an additional 0.3% (n=8) were eroded and unidentified otoliths. A total of 63 squid beaks (preliminary ID: *Brachioteuthis picta*) were collected from 19.1% of the scats.

E. Fatty Acid Signature Analysis of Milk: In addition to scats, we collected 65 milk samples from 36 female fur seals. Each time a female was captured (either to instrument or to remove instruments), ≤30mL of milk was collected by manual expression. Prior to collection of the milk sample, an intra-muscular injection of oxytocin (0.25mL, 10 UI/mL) was administered. Milk was returned (within several hours) to the lab where two 0.25mL aliquots were collected and each stored in a solvent-rinsed glass tube with 2mL of chloroform with 0.01% butylated hydroxytoluene (BHT, an antioxidant). Samples were flushed with nitrogen, sealed, and stored frozen for later extraction of lipid and trans-esterification of fatty acids. Of the 65 samples, 29 were collected from perinatal females and 22 were collected from females that had dive data for the foraging trip prior to milk collection.

F. Diving Studies: Twelve of 27 females outfitted with a transmitter for attendance studies also received a time-depth recorder (TDR, Wildlife Computers Inc., Mark 9s, 66 x 18 x 18mm, 31g) on their first visit to shore. All females carried their TDRs for at least their first six trips to sea. In addition, all other females captured for studies of at-sea foraging locations also received a TDR. A total of 22 dive records were collected from 17 females in 2007/08. No TDRs were lost this season.

G. Adult Female Foraging Locations: We instrumented 10 females with GPS (Global Positioning System) TDRs (Mk10-F; Wildlife Computers, Inc.) with fast-loc technology. One female carried both an Mk10-F and an ARGOS satellite-linked transmitter (SPOT5; Wildlife Computers, Inc.). The first five of these deployments occurred 20 December – 17 January. The remaining five were deployed to coincide with the U.S.-AMLR oceanographic survey in January (Leg 1). They were deployed 18 January – 3 February. An additional three females were instrumented with ARGOS PTTs (SPOT5, Wildlife Computers, Inc.) beginning 30 January. These three females were part of a study of overwinter dispersal and were not recaptured to remove their instruments. A total of 46 trips to sea were recorded with GPS and ARGOS instruments for three sampling periods (December, January, February) in 2007/08 (Figure 6.4).

H-J. Demography and Tagging: Together, Chilean and U.S. researchers tagged 496 fur seal pups (256 females, 240 males) from 9 February – 2 March 2008. All tags placed at Cape Shirreff were Dalton Jumbo Roto tags with white tops and orange bottoms. Each pup was tagged on both fore-flippers with identical numbers. Series numbers for 2007/08 were 5501-6000 (tags 5526, 5534, 5848, and 5989 were lost or damaged and not deployed). Tag deployment distribution was different than in previous years. Usually all pups are tagged on study beaches on the east side of the Cape from Playa Marko to Ballena Norte beach. However, protocol for distribution of tags was changed by one tagging team to facilitate collection of DNA samples by the Chilean program. Approximately 50% of the tags were distributed over the entire Cape.

In addition to the 496 pups tagged, we also retagged two adult lactating females (287, 1615) and added fourteen new tags to the adult female population (413, 417-429, 431).

K. Age Determination Studies: We began an effort of tooth extraction from adult female fur seals for age determination in 1999/00. Tooth extractions are made using gas anesthesia (isoflurane, 2.5-5.0%), oxygen (4-10 liters/min), and midazolam hydrochloride (1cc). A detailed description of the procedure was presented in the 1999/00 annual report.

This year we took a single post-canine tooth from only 10 previously tagged females. The mean age of the sample was 11.5 years (± 1.11, N=10).

L. Weather at Cape Shirreff: A weather data recorder (Davis Weather Monitor II) was set up at the U.S.-AMLR field camp at Cape Shirreff from 10 November 2007 to 5 March 2008. The recorder archived wind speed and direction, barometric pressure, temperature, humidity, and rainfall at 15-minute intervals. The sampling rate for wind speed, temperature, and humidity was every eight seconds; the averaged value for each 15-minute interval was stored in memory. Barometric pressure was measured once at each 15-minute interval and stored. When wind speed was greater than 0, the wind direction for each 8-second interval was stored in one of 16 bins corresponding to the 16 compass points. At the end of the 15-minute archive interval, the most frequent wind direction was stored in memory.

M. Entangled pinnipeds: We recorded six fur seals, five male and one female, with marine debris around their necks. Five had net fragments or rope and one had a plastic packing band. Three of the six had their debris successfully removed.

N. Other pinnipeds: Southern elephant seals. The U.S.-AMLR program, in collaboration with University of California researchers, tagged 13 elephant seal pups (five male, eight females), 11 adult females and one adult male. The adult females and one sub-adult male were captured post-molt and were also instrumented with ARGOS satellite-linked transmitters for post-molt dispersal at sea.

O. Other pinnipeds: Leopard seals. During the summer months (Nov-Feb, the only months of human occupation of Cape Shirreff), Leopard seals are frequently observed hauling out on beaches around Cape Shirreff. Leopard seals are frequently observed preying on fur seal pups and penguins. During January and February, Leopard seals consume as much as half of all fur seal pups born on the Cape. They represent a significant top-down force influencing fur seal population growth (Boveng et al. 1998). To better understand the role of Leopard seals within the region and their influence on krill-dependent predators, we began a study of foraging range and dispersal. In 2007/08, we captured and instrumented our first Leopard seals. Four leopard seals were instrumented with ARGOS PTTs (Platform Terminal Transmitter) from 29 January – 2 February. Attachments were made after first sedating with 40-45 mL of 5mg/mL (200-225 mg) midazolam. All four instruments transmitted from initial deployment through April. Two of the four seals remained at Cape Shirreff during this period and two others moved east to Robert Island. There are no known fur seals colonies at Robert Island (Figure 6.5).

P. South Shetland Islands fur seal pup production survey. The last archipelago-wide survey of fur seal pup production was completed in February 2002. In that survey, sites were visited and particular effort focused on establishing whether fur seals had begun to re-colonize any sites on the southern shores of the South Shetland Islands in the Bransfield Strait. Although male fur seals haul out in relative abundance in those areas, no females or pups were observed. In keeping with past efforts to expand coverage at each survey, this year's survey explored more areas of the Beyer's Peninsula and Rugged Island.

The other goal for this year's survey was to accomplish as much as possible of the survey before the start of Leopard seal predation on fur seal pups, which begins when pups begin entering the water (early January).

Distribution of fur seal breeding colonies is such that >85% of all pups are born in the western part of the archipelago. Almost all of these are born on Cape Shirreff, Livingston Island and the San Telmo Islands located off the northwestern shores of Cape Shirreff. Nearby Window Island and Ray's Promontory of the Beyer's Peninsula are additional sites very close to Cape Shirreff with breeding populations of fur seals. Thus our effort prior to 17 January was focused on these islands and beaches.

Less than 15% of pup production occurs around the Elephant Island area in the northern and eastern reaches of the archipelago, with one additional colony breeding at Stigant Pt., King George Island. The Elephant Island area, because of logistics and competing research interests, was not surveyed until early February, at least two weeks after the start of Leopard seal predation.

Counts were taken using multiple counters (4-8 for any one site). Counters moved slowly along a beach counting live pups and then, once live pups are counted; a count of dead pups was made. At some sites dead pups were counted by a team of 3-4 counters counting only dead pups. Any counts 10% or more off the mean were discarded and the mean re-calculated. A total of 10 counts out of 131 individual counts (7.6%) of 31 beaches/sites were discarded. Some Seal Island sites were estimated based on prior surveys with adjustments based on relative numbers of this survey compared to the 2002 survey. Cape Lindsey was visited but weather and sea conditions prevented landings. Thus this site was also estimated in the same way as described for Seal Islands.

Total pup production was 7,602 (±103) pups, down 24.4% from the last census in 2001/02 (10,057 ±142 pups born). However, these numbers are raw counts and are not adjusted for Leopard seal predation, early season mortality (unaccounted-for mortality of washed-away or scavenged dead pups at the time of census), or natality rates (i.e. total number of females giving birth).

Sites visited for the survey and the ship track-line are presented in Figure 6.6. The 2008 Antarctic fur seal pup survey was a joint effort between U.S. AMLR and the Instituto Antartida de Chile (INACH).

6.3 Preliminary Conclusions: Fur seal pup production during 2007/08 at U.S. AMLR study beaches showed a decline (12.5%) over previous years. Early season neonate mortality (4.2%) was slightly lower than the long-term average of 4.5%. We also recorded a mid-season increase in Leopard seal predation over last year. The median date of pupping based on pup counts was one day earlier than last year. Over-winter survival for adult females decreased over last year (86.5 vs. 88.9%), and is well below the long-term mean (10 year mean: 89%). The natality rate also decreased (84.9 vs. 88.5%). The mean foraging trip duration (3.69 days ±0.17) increased by a day over last year and was slightly lower than the long-term mean (3.8 days ±0.36). Visit duration (1.35 days ±0.08) showed a similar trend and, like trip durations, were reflective of less favorable summer foraging conditions than in 2006/07. Like adult female survival, over-winter juvenile survival in 2007 was also lower than in 2006. Tag resights for the 2004/05 cohort this year confirmed, as in 2005/06 and 2006/07, a poor rate of success for that cohort. No tag returns have ever been recorded for the 2004 cohort. The 1999/00 and the 2001/02 cohorts, even with decreased survival for 2007, continued to dominate tag returns. For the first time in four years *Electrona carlsbergi* was recorded in fur seal diet. In general, both winter and summer conditions were less favorable compared to 2006/07 resulting in average performance for summer indices; and below average performance for indices reflective of winter conditions.

6.4 Disposition of Data: All raw and summarized data are archived by the Antarctic Ecosystem Research Division of the National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, CA 92037.

6.5 Problems and Suggestions: The monitoring program at Cape Shirreff is confined to measuring parameters during the first three months of fur seal pup rearing. Only a few of the summer-measured parameters (e.g. adult female over-winter survival, pregnancy rates, and cohort survival) reflect ecological processes over a broader temporal spatial scale. Yet these data suggest that post-weaning environments are important for survival, recruitment, and sustainability of the Cape Shirreff fur seal population. The dominance of the 1999/00 cohort in tag return data and differential cohort strength offer one of the best examples of this. Recent technology in miniaturization and programmability of satellite-linked transmitters provide the means by which to develop an understanding of post-weaning environments, dispersal of females and pups post-weaning. These instruments not only provide information on dispersal, but they can also measure the physical environment encountered by individuals. Future studies should use this technology to measure dispersal, survival and various parameters of the physical environment in order to identify factors leading to increased survival and recruitment of juvenile pinnipeds and seabirds.

6.6 Acknowledgements: The National Science Foundation provided support and transportation to the Cape Shirreff field site for the opening camp crew. We thank the captain, crew and science staff of the November cruise of the R/V *Laurence M. Gould*. We are grateful to our Chilean colleagues: Daniel E. Torres, Susan Abuito, Veronica Villalobos, and Pilar Diaz, for their assistance in the field and for sharing their considerable knowledge and experience of Cape Shirreff. We thank Sarah Chisholm and Kevin Pietrzak for their help with pinniped studies. We are, likewise, grateful to Anthony Cossio, Christian Reiss, and all the AMLR personnel, and the Russian crew of the R/V *Yuzhmorgeologiya* for their invaluable support and assistance to the land-based AMLR personnel. All pinniped research at Cape

Shirreff was conducted under Marine Mammal Protection Act Permit No. 774-1847-02 granted by the Office of Protected Resources, National Marine Fisheries Service. Elephant seal research at Cape Shirreff in 2007/08 was supported by a National Science Foundation grant to D. Costa, University of California-Santa Cruz, D. Crocker, Sonoma State University, and M. Goebel, U.S.-AMLR Program.

6.7 References:

Boveng, P.L., Hiruki, L.M., Schwartz, M.K., and Bengtson, J.L. 1998. Population growth of Antarctic fur seals: limitation by a top predator, the leopard seal. Ecology 79 (8): 2863-2877.

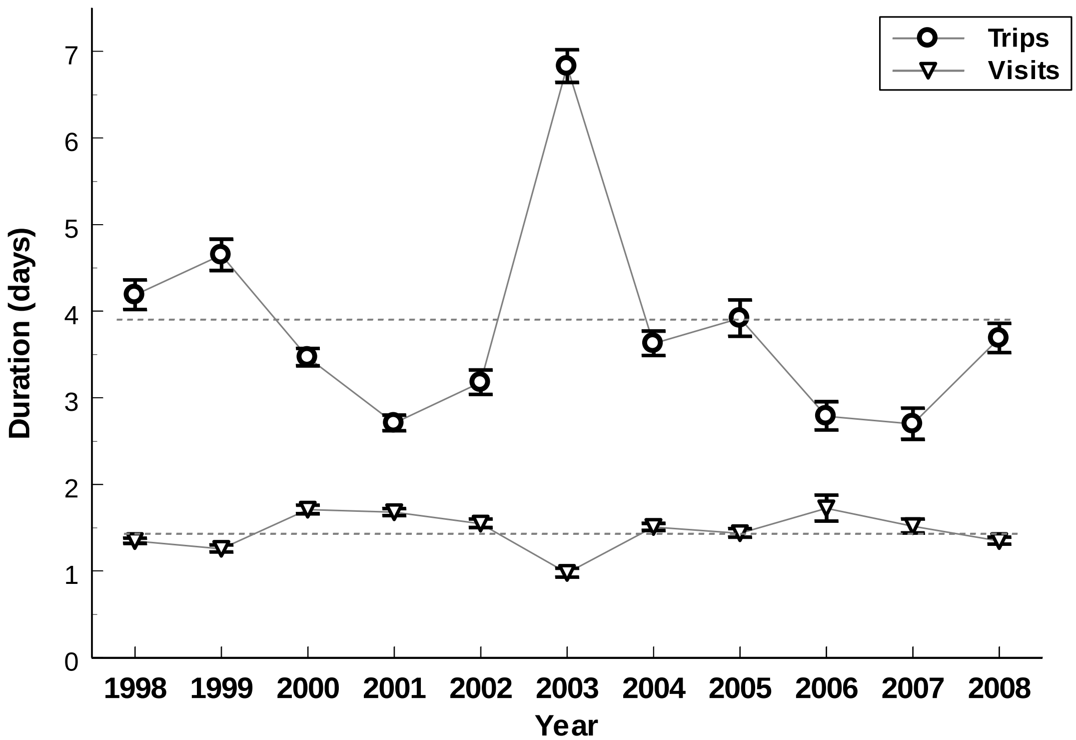


Figure 6.1. Antarctic fur seal mean trip and visit durations (with standard error) for females rearing pups at Cape Shirreff, Livingston Island. Data plotted are for the first six trips to sea and the first six non-perinatal visits following parturition. Long-term means are plotted as dashed gray lines.

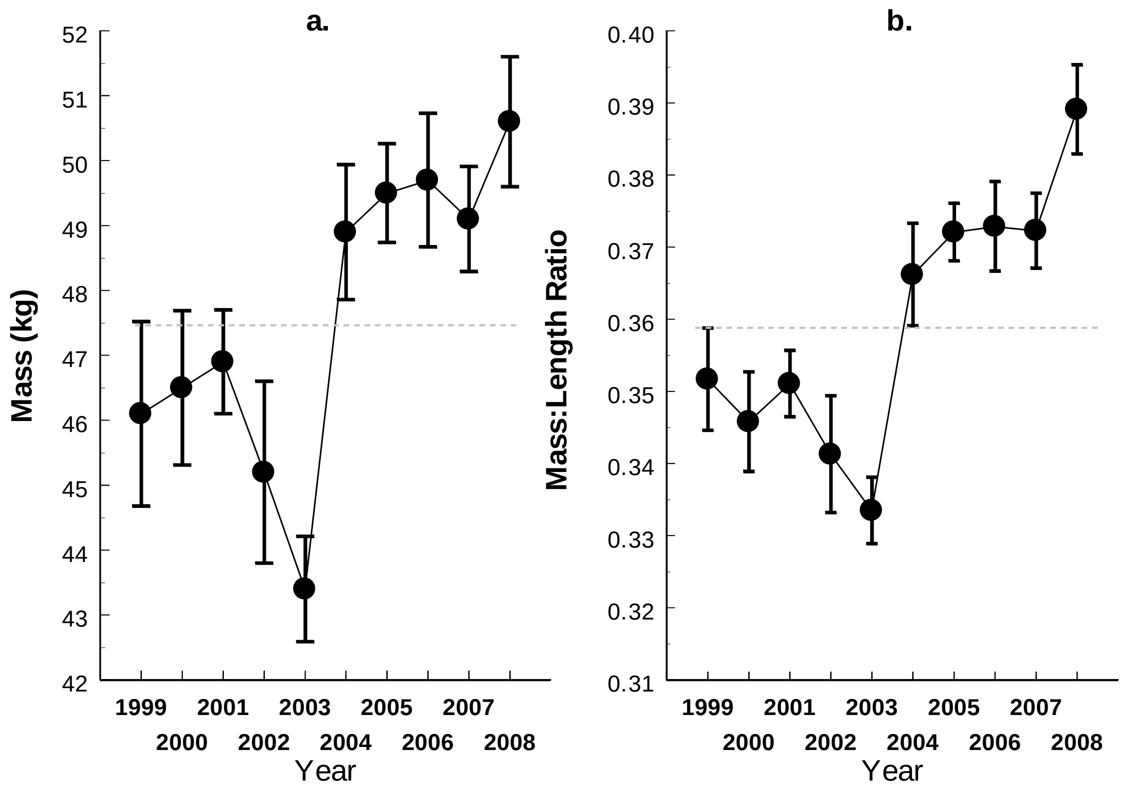


Figure 6.2. The mean mass (a.) and mass:length ratio (b.) for females at parturition, 1998/99 – 2007/08 (98/99: N=32, 99/00: N=23, 00/01, 04/05: N=29, 01/02-03/04, 05/06: N=28, 06/07: N=21, 07/08: N=29). Long-term average is plotted as a gray dashed line (mass: 47.6 ±0.73; mass:length ratio: 0.359 ±0.006).

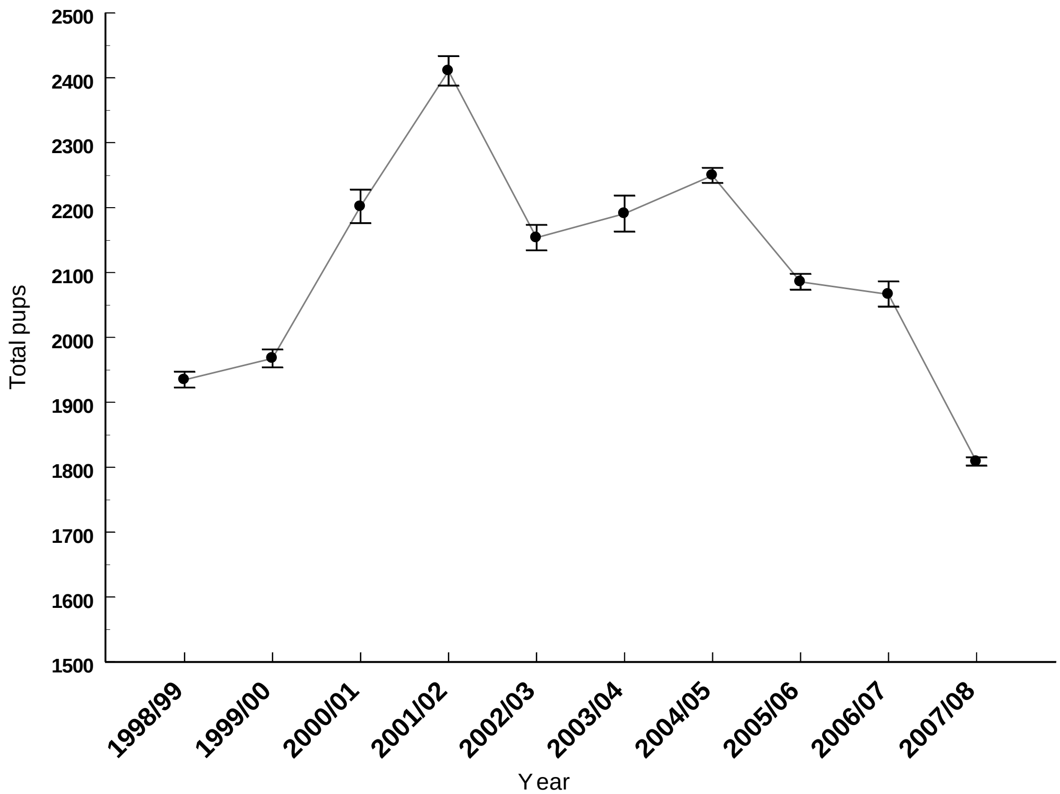


Figure 6.3. Antarctic fur seal pup production at U.S. AMLR study beaches, Cape Shirreff, Livingston Island, 1998/99-2007/08.

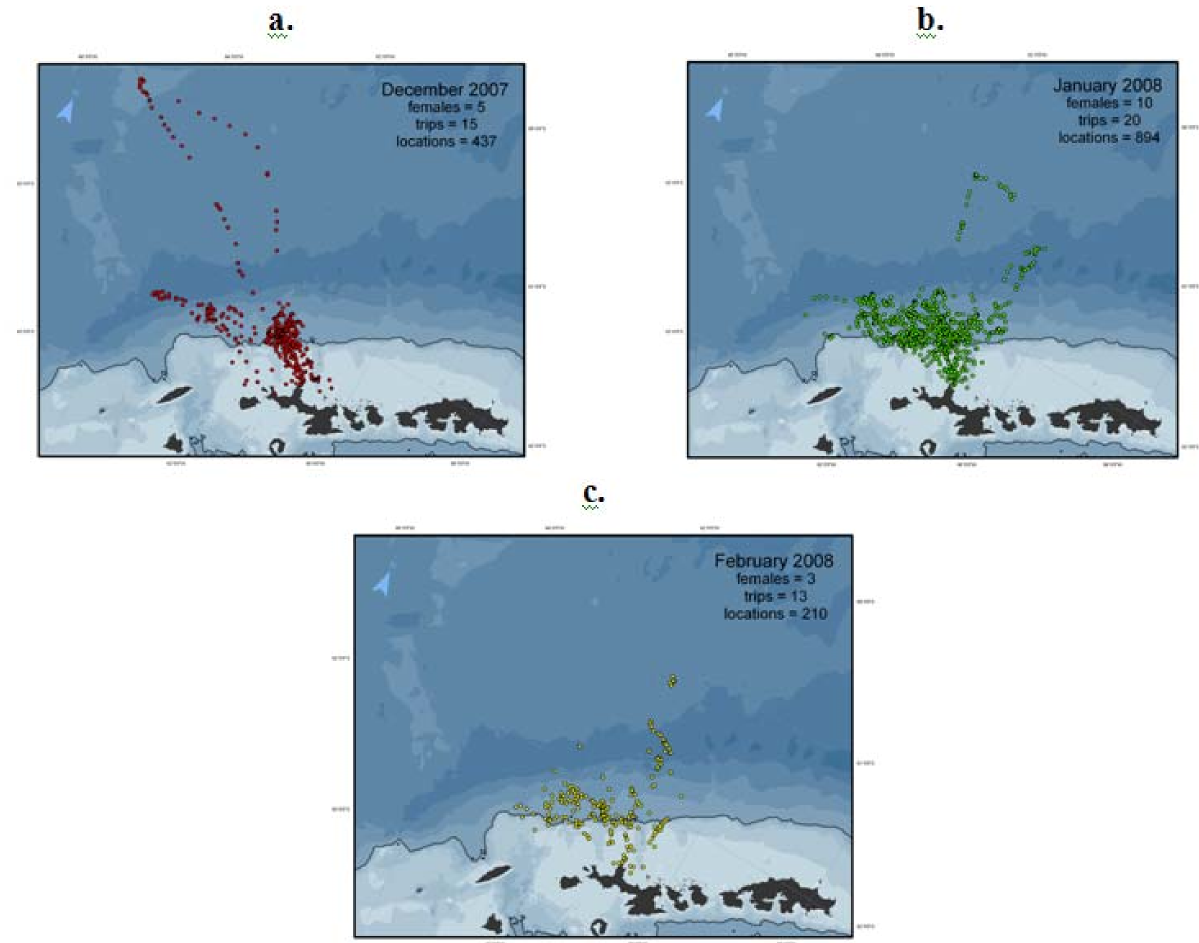


Figure. 6.4. At-sea locations of lactating Antarctic fur seals in a) December (red), b) January (green), and c) February (yellow) foraging from Cape Shirreff, Livingston Island, South Shetland Islands, 2007/08. The 500m bathymetry is outlined to show the location of the continental shelf edge.

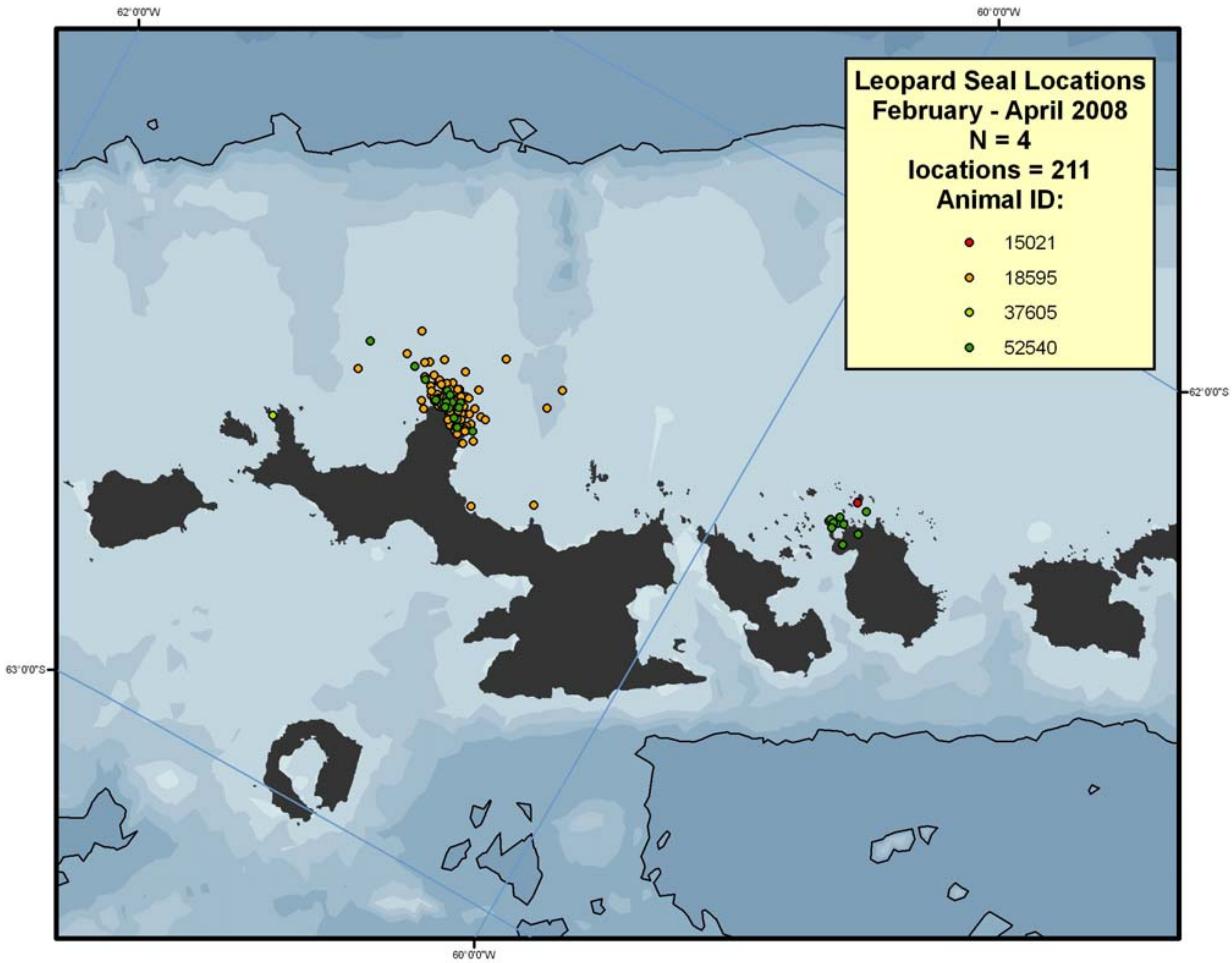


Figure 6.5. ARGOS locations for four Leopard seals from February through April, 2007/08. The largest island is Livingston Island and the 500 meter bathymetry is outlined to show the area of continental shelf.

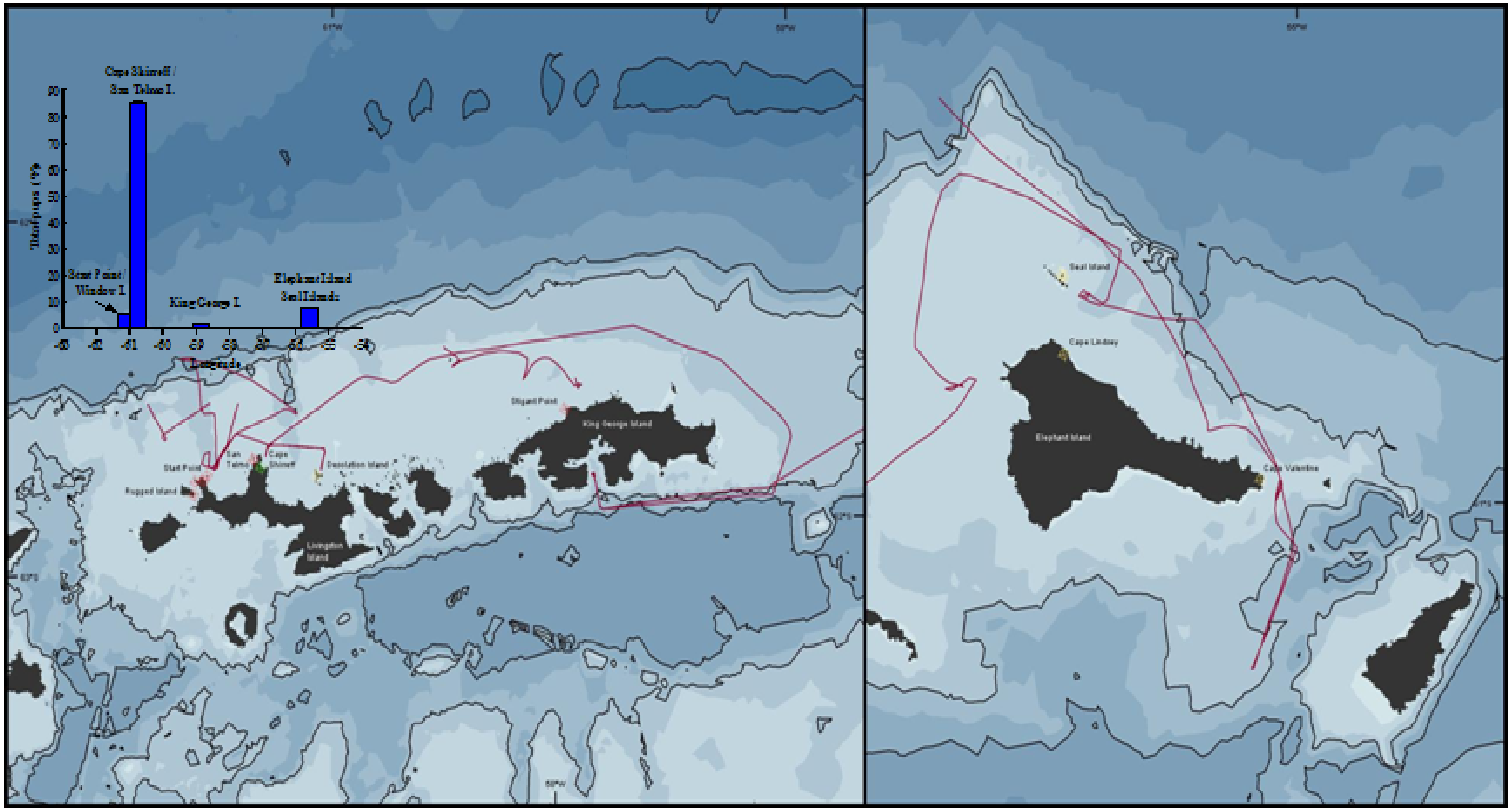


Figure 6.6. The South Shetland Islands, showing sites visited and the ship's track line for the 2008 Antarctic fur seal pup production survey. The inset shows distribution of pups born (% total) in the South Shetlands by longitude.

7. Distribution, Abundance and Behavior of Seabirds and Mammals at sea during the 2007/08 AMLR Survey; submitted by Jarrod A. Santora, Michael P. Force and Thomas Brown

7.1 Objectives:

This investigation focused on the at-sea distribution and density of seabirds and marine mammals during the 2007/08 AMLR Survey. The primary objective was to map the density and distribution of seabirds and mammals at sea. The resulting data set, summarized in this report, will be used to investigate:

a) Impact of krill abundance and patchiness on seabirds and mammals,
b) Community structure and habitat selection by predator groups, and
c) Inter-annual and seasonal change in the spatial distribution of foraging seabirds and mammals at sea.

7.2 Methods:

7.2.1 Seabird and Mammal Observations: Data on predator abundance and behavior were collected using binoculars while underway between stations during daylight hours. Surveys followed strip transect methods (Tasker *et al*., 1984) and counts were made within an arc of 300m directly ahead and to one side of the ship. In this report, transects are defined as the duration of travel and space covered while the vessel was underway between stations. Each record was assigned a time and a position directly fed by the ship's navigational computer, which was synchronized with the ship's data acquisition computer and the hydro-acoustic system used to collect krill biomass estimates. Individual birds, or flocks of birds, were assigned a behavioral code. The behaviors were: flying, sitting on water, milling (circling), feeding, porpoising (penguins, seals, and dolphins) and ship-following. Ship-followers were entered when encountered and were ignored thereafter. Predators that were flying or porpoising were assigned a direction of travel. Data recorded for mammals included traveling direction, distance from ship and behavior. All sightings were downloaded, error checked and stored in a database each day.

7.3 Accomplishments:

Underway observations of predators were successfully conducted during Legs I and II of the 2007/08 AMLAR Survey. Data on the abundance of seabirds and marine mammals per AMLR Survey stratum, as well as distribution maps of the most common seabirds, pinnipeds and cetaceans, are presented in this report. A brief summary of the survey follows.

7.4 Results and Tentative Conclusions:

7.4.1 Leg I Summary: Approximately 4148km of survey effort were collected during Leg I (Table 8.1). The density (#/km) of seabirds and mammals recorded during Leg I is presented in Table 8.2. Densities are calculated by dividing the total abundance by the total kilometers surveyed in each stratum (Table 8.2). The distribution (#/10nmi) of total seabirds, feeding aggregations, Antarctic Fur Seals (*Artcocephalus gazella*) and Humpback Whales (*Megaptera novaeangliae*) recorded during Leg I is presented in Figures 8.1-8.4.

Seabird feeding aggregations were found along the shelf break region from north of King George Island and throughout the Elephant Island Area (Figure 8.2). The feeding aggregations (primarily Cape Petrels *Daption capense*) occurred in proximity to a surface temperature front traversing the West and Elephant Island Areas.

Foraging distributions of Antarctic Fur Seals were widespread in the AMLR Survey Area during Leg I (Figure 8.3), a distribution pattern that has not been observed since AMLR 2003 (Santora et al. 2003).

Moreover, Antarctic Fur Seals were highly conspicuous in the South stratum, with the highest numbers occurring near the ice edge in the vicinity of the Antarctic Sound and Joinville Island (Figure 8.3).

As in past AMLR surveys, Humpback Whales were concentrated in coastal waters near the South Shetland Islands and throughout the deep basins in Bransfield Strait (Figure 8.4).

A Southern Right Whale (*Eubalaena australis*) was observed on the last transect in the Elephant Island region adjacent to Clarence Island, and also near Deception Island. This is the first time this species has been observed during an AMLR Survey since 2004.

7.4.2 Leg II Summary: Distribution of predators was mapped during the survey of the Elephant Island and the South Orkneys Areas. Approximately 2012km of survey effort were collected during Leg II (Table 8.1). The density of seabirds and mammals recorded during Leg II is presented in Table 8.2. Densities are calculated by dividing the total abundance by the total kilometers surveyed in each stratum (Table 8.2). The distribution of Cape Petrels, Southern Fulmars (*Fulmarus glacialoides)*, Black-browed (*Thalassarche melanophrys*) and Grey-headed Albatrosses (*T. chrysostoma*), Chinstrap Penguins (*Pygoscelis antarctica*), Prions (*Pachyptila spp.*), Antarctic Fur Seals, and Fin Whales (*Balaenoptera physalus*) recorded during Leg II is presented in Figures 8.4-8.8.

7.4.2.1 South Orkney Islands: In the vicinity of the Inaccessible Islands, numerous aggregations of seabirds (primarily Cape Petrels and Southern Fulmars, numbering in the thousands) were observed continuously during transit for 30 nautical miles. In this same region three krill fishing vessels were observed (a few km away from the survey line), one of which was actively fishing. No seabird aggregations were encountered east of this region. Additionally, a total of 34 Fin Whales and 5 Humpback Whales were observed. All were observed in the northwest shelf region near Coronation Island and Inaccessible Islands.

There were fewer seabirds on the southern shelf than on the northern shelf near the South Orkney Islands. No feeding aggregations of seabirds were encountered. There was a sighting of a Southern Right Whale and a sighting of 3 Killer Whales (Type A).

7.4.2.2 Elephant Island: The seabird community near Elephant Island consisted primarily of: Cape Petrel, Southern Fulmar, Chinstrap Penguin, Wilson's Storm Petrel (*Oceanites oceanicus*), Black-bellied Storm Petrel (*Fregetta tropica*) Southern Giant Petrel, Prions, Black-browed and Grey-headed Albatross, and White-chinned Petrel (*Procellaria aequinoctialis*).

More feeding aggregations of seabirds were ecountered near Elephant Island (primarily Cape Petrel and Black-browed Albatross) than in the South Orkney Islands Area (Figure 8.5). Feeding aggregations of seabirds were encountered along the boundary of Southern Antarctic Circumpolar Current.

Fin Whales were highly conspicuous in the waters near Elephant Island. There were 97 sightings of Fin Whale groups for a total of 234 fin whales. The largest concentrations of whales were encountered to the northeast and southeast of Elephant Island. The substantial increase in Fin Whales observed during Leg II suggests a probable response to the seasonal change in krill distribution (see Zooplankton, this report). Additionally, 2 Right Whales were observed near the shelf break north of Elephant Island.

7.5 Disposition of Data:

After all data have been thoroughly proofed, a copy will be available from Jarrod Santora, phone: (917) 647-4692; email: jasantora@gmail.com

7.6 Acknowledgements:

Everyone involved in the 2007/08 AMLR field season; especially the captain and crew of the RV Yuzhmorgeologiya for maintaining the viewing platform on the flying bridge.

7.7 References:

Tasker, M.L., Jones, P.H., Dixon, T., and Blake, B.F. 1984. Counting seabirds at sea from ships: A review of methods employed and a suggestion for a standardized approach. *Auk* 101: 567-577.

Santora, JA, and SS Mitra. 2003. Distribution, abundance, and behavior of seabirds and mammals at sea, in response to variability of Antarctic krill and physical oceanography during the 2003 AMLR survey. Lipsky, J. (ed) NOAA-TM-NMFS-SWFSC-355. pp 204-217

Table 7.1. Survey effort (km) by AMLR strata.

SURVEY A	ELEPHANT	JOINVILLE	SOUTH	WEST	Total
	1354	381	949	1464	4148
SURVEY D	ELEPHANT	ORKNEYS			
	1109	963			2072
TOTAL	2463				6220

Table 7.2. Seabird and marine mammal density (#/km per stratum) during Leg I AMLR 2007/08.

Common Name	Latin Name	Elephant	Joinville	South	West	Total
Adelie Penguin	*Pygocelis adleie*	0	2.034121	0.671	0	0.34041
Gentoo Penguin	*Pygocelis papua*	0.000739	0.08399	0.062	0.02254	0.03014
Chinstrap Penguin	*Pygocelis antarctica*	0.909897	1.787402	0.867	0.11954	0.70178
Macaroni Penguin	*Eudyptes chrysolophus*	0	0	0	0	0
Wandering Albatross	*Diomedea exulans*	0.005908	0	0	0.00273	0.00289
Royal Albatross	*Diomedea epomorpha*	0	0	0	0	0
Black-browed Albatross	*Thalassarche melanophrys*	0.067947	0.007874	0.032	0.07172	0.05545
Grey-headed Albatross	*Thalassarche chrysostoma*	0.016248	0	0.002	0.00888	0.00892
Light-mantled Sooty Albatross	*Phoebetria palpebrata*	0.007386	0	0	0.00273	0.00338
Sooty Albatross	*Phoebetria fusca*	0	0	0	0.00068	0.00024
Southern Giant Petrel	*Macronectes giganteus*	0.031758	0.086614	0.044	0.02322	0.03664
Northern Giant Petrel	*Macronectes halli*	0.00517	0	0	0.00068	0.00193
Southern Fulmar	*Fulmarus glacialoides*	0.090842	1.380577	0.556	0.0082	0.28664
Antarctic Petrel	*Thalassoica antarctica*	0.000739	0.081365	0	0	0.00771
Cape Petrel	*Daption capense*	1.288774	0.251969	0.068	1	0.81244
White-chinned Petrel	*Procellaria aequinoctialis*	0.022157	0	0	0.03893	0.02097
Soft-plumaged Petrel	*Pterodroma mollis*	0.002216	0	0	0	0.00072
Snow Petrel	*Pagodroma nivea*	0	0.002625	0	0	0.00024
Antarctic Prion	*Pachyptila desolata*	0.031019	0	0.002	0.02869	0.02073
Blue Petrel	*Halobaena caerulea*	0.022157	0	0	0.09973	0.04243
Wilson's Storm Petrel	*Oceanites oceanicus*	0.120384	0.380577	0.177	0.08948	0.14634
Black-bellied Storm Petrel	*Fregetta tropica*	0.139586	0.031496	0.014	0.12432	0.09547
Brown Skua	*Catharacta antarctica*	0.000739	0	0.003	0.00137	0.00145
South Polar Skua	*Catharacta maccormicki*	0.008863	0.007874	0.019	0.00546	0.00988
Kelp Gull	*Larus dominicanus*	0	0.005249	0.001	0	0.00072
Antarctic Tern	*Sterna vittata*	0.006647	0.005249	0.007	0.00888	0.00747
Antarctic fur seal	*Artcocephalus gazella*	0.090842	0.089239	0.152	0.02869	0.08269
Elephant Seal	*Mirounga leoina*	0	0	0	0.00068	0.00024
Weddell Seal	*Leptonychotes weddellii*	0	0.002625	0.002	0	0.00072
Crabeater Seal	*Lobodon carcinophagus*	0	0.020997	0	0	0.00193
Southern Right Whale	*Eubalaena australis*	0.000739	0	0.001	0	0.00048
Humpback whale	*Megaptera Novaeangliae*	0.014032	0.154856	0.073	0.02322	0.04364
Fin Whale	*Balaenoptera physalus*	0.022157	0.007874	0	0	0.00796
Minke Whale	*Balaenoptera bonaerensis*	0	0	0.002	0.00068	0.00072
Un-identified Whale	*Balaenoptera species*	0	0	0	0.00205	0.00072
Southern Bottlenose Whale	*Hyperoodon planifrons*	0	0	0	0	0
Mesoplodon sp.	*Mesoplodon sp.*	0	0	0	0.00068	0.00024

Table 7.3. Seabird and marine mammal density (#/km per stratum) during Leg II AMLR 2007/08.

Common Name	Latin Name	Elephant	Orkneys	Total
Chinstrap Penguin	*Pygocelis antarctica*	**0.391344**	**0.976116**	**0.663127**
Wandering Albatross	*Diomedea exulans*	**0.009017**	**0.013499**	**0.0111**
Black-browed Albatross	*Thalassarche melanophrys*	**0.132552**	**0.106957**	**0.120656**
Grey-headed Albatross	*Thalassarche chrysostoma*	**0.087466**	**0.053998**	**0.071911**
Light-mantled Sooty Albatross	*Phoebetria palpebrata*	**0.009017**	**0.008307**	**0.008687**
Southern Giant Petrel	*Macronectes giganteus*	**0.150586**	**0.07892**	**0.117278**
Northern Giant Petrel	*Macronectes halli*	**0.003607**	**0.004154**	**0.003861**
Southern Fulmar	*Fulmarus glacialoides*	**0.889991**	**2.333333**	**1.560811**
Cape Petrel	*Daption capense*	**2.605951**	**8.235722**	**5.22249**
White-chinned Petrel	*Procellaria aequinoctialis*	**0.045987**	**0.126687**	**0.083494**
White-headed Petrel	*Pterodroma lessonii*	**0.000902**	**0**	**0.000483**
Soft-plumaged Petrel	*Pterodroma mollis*	**0.018034**	**0.001038**	**0.010135**
Kerguelen Petrel	*Lugensa brevirostris*	**0.001803**	**0.001038**	**0.001448**
Snow Petrel	*Pagodroma nivea*	**0.000902**	**0.024922**	**0.012066**
Antarctic Prion	*Pachyptila desolata*	**0.150586**	**0.085151**	**0.120174**
Un-identified Prion	*Pachyptila spp.*	**0.122633**	**0.629283**	**0.358108**
Blue Petrel	*Halobaena caerulea*	**0.015329**	**0.003115**	**0.009653**
Wilson's Storm Petrel	*Oceanites oceanicus*	**0.293057**	**0.186916**	**0.243726**
Black-bellied Storm Petrel	*Fregetta tropica*	**0.136159**	**0.125649**	**0.131274**
Common Diving Petrel	*Pelecanoides urinatrix*	**0.001803**	**0**	**0.000965**
South Georgia Diving Petrel	*Pelecanoides georgicus*	**0.000902**	**0**	**0.000483**
Brown Skua	*Catharacta antarctica*	**0.008115**	**0.001038**	**0.004826**
South Polar Skua	*Catharacta maccormicki*	**0.009017**	**0.001038**	**0.005309**
Antarctic Tern	*Sterna vittata*	**0.008115**	**0.001038**	**0.004826**
Antarctic fur seal	*Artcocephalus gazella*	**0.066727**	**0.085151**	**0.07529**
Weddell Seal	*Leptonychotes weddellii*	**0.000902**	**0**	**0.000483**
Southern Right Whale	*Eubalaena australis*	**0.001803**	**0.001038**	**0.001448**
Humpback whale	*Megaptera Novaeangliae*	**0.002705**	**0.004154**	**0.003378**
Fin Whale	*Balaenoptera physalus*	**0.211001**	**0.009346**	**0.117278**
Minke Whale	*Balaenoptera bonaerensis*	**0.000902**	**0**	**0.000483**
Un-identified Whale	*Balaenoptera species*	**0**	**0.001038**	**0.000483**

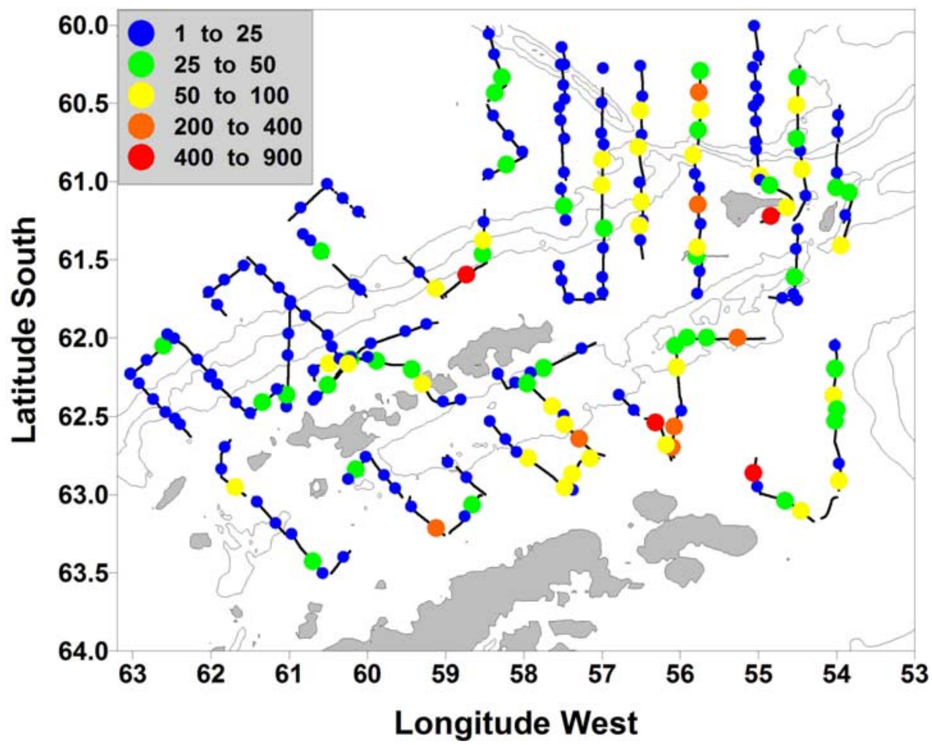


Figure 7.1. Distribution of Total Seabirds (#/10nmi) Leg I.

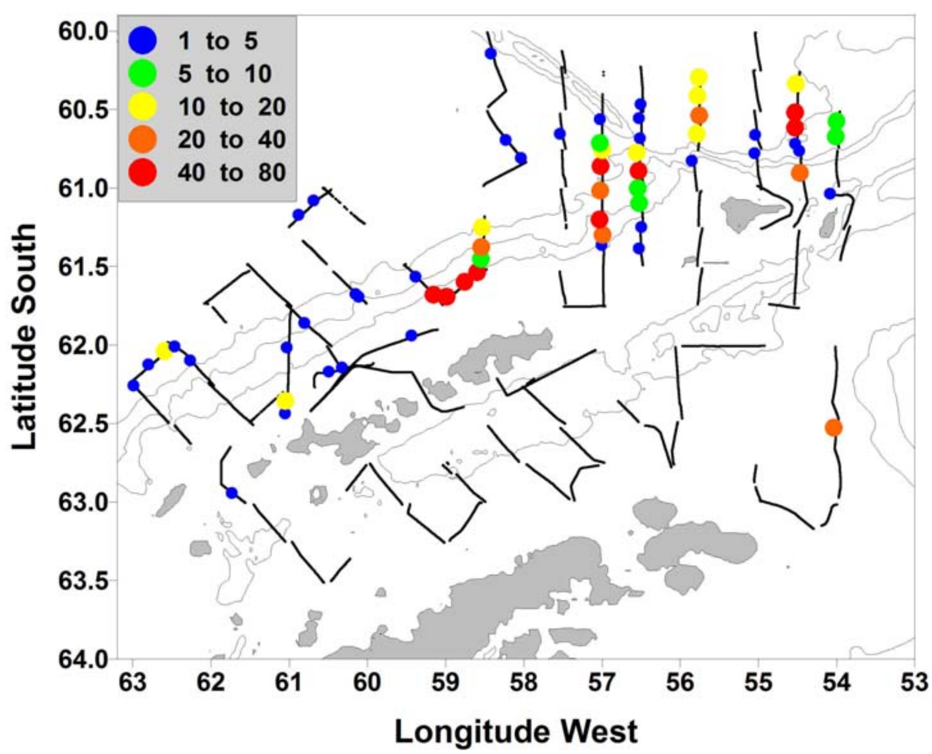


Figure 7.2. Distribution of Seabird Feeding Aggregations (#/10nmi) Leg I.

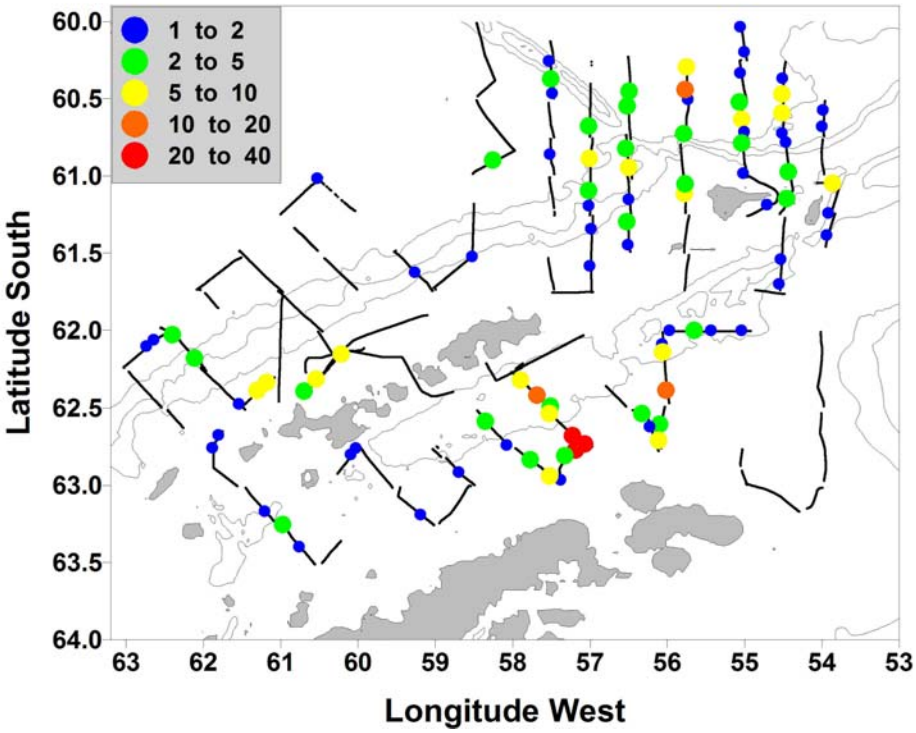


Figure 7.3. Distribution of Antarctic Fur Seals (#/10nmi) Leg I.

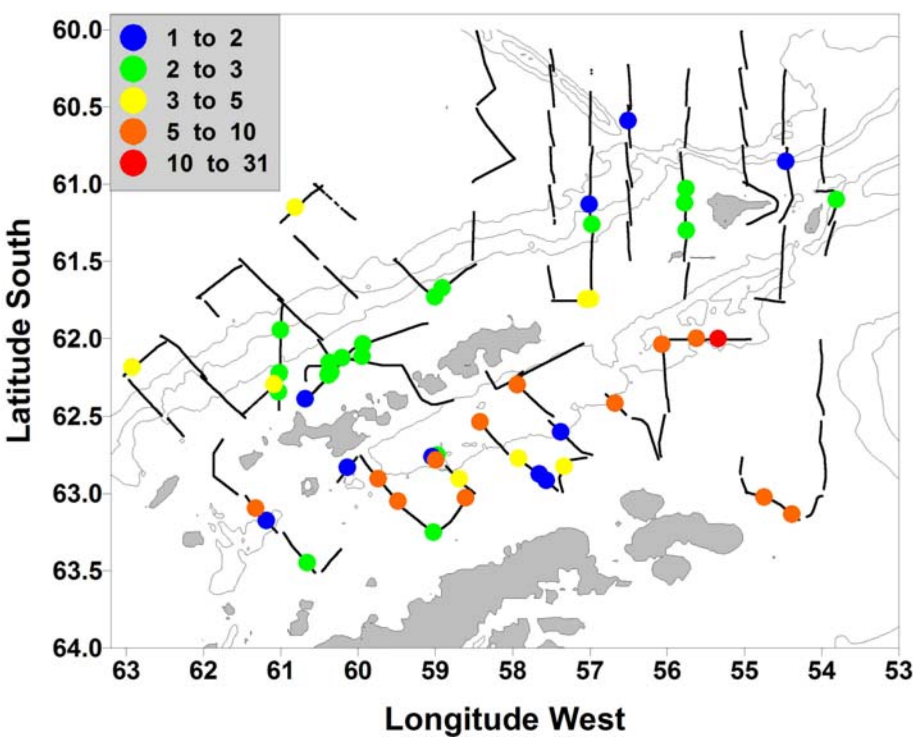


Figure 7.4. Distribution of Humpback Whales sightings (#/10nmi) Leg I.

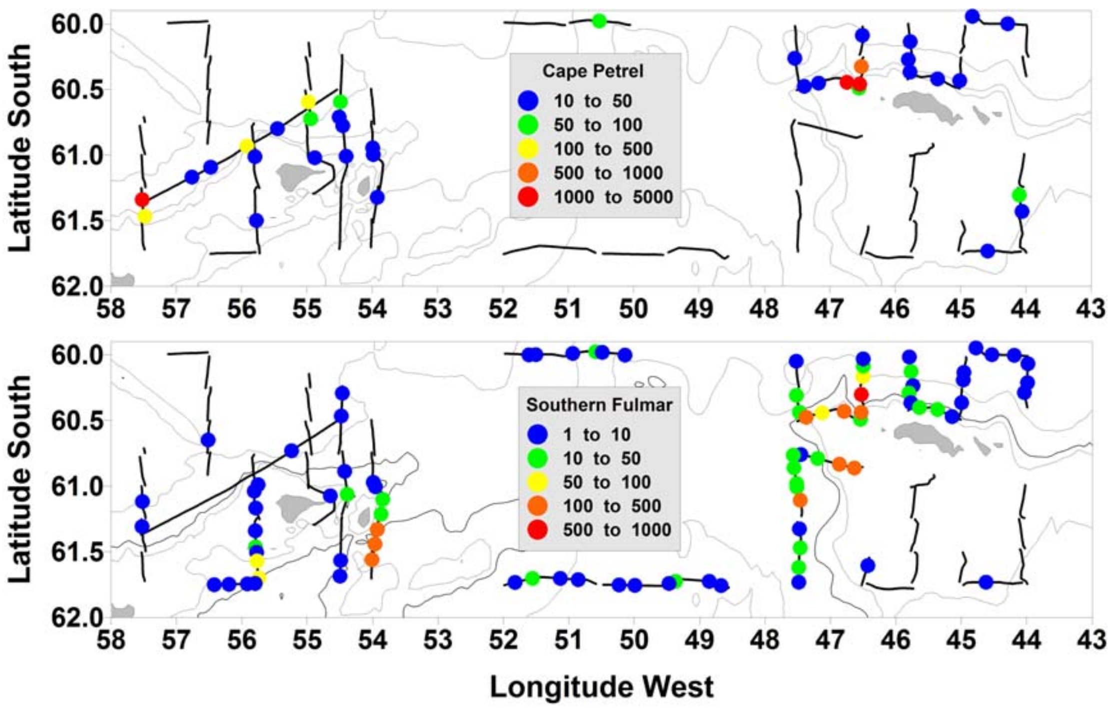


Figure 7.5. Distribution (#/10nmi) of Cape Petrel (top) and Southern Fulmar (bottom) during Leg II AMLR08; Elephant Island (left) South Orkney Islands (right).

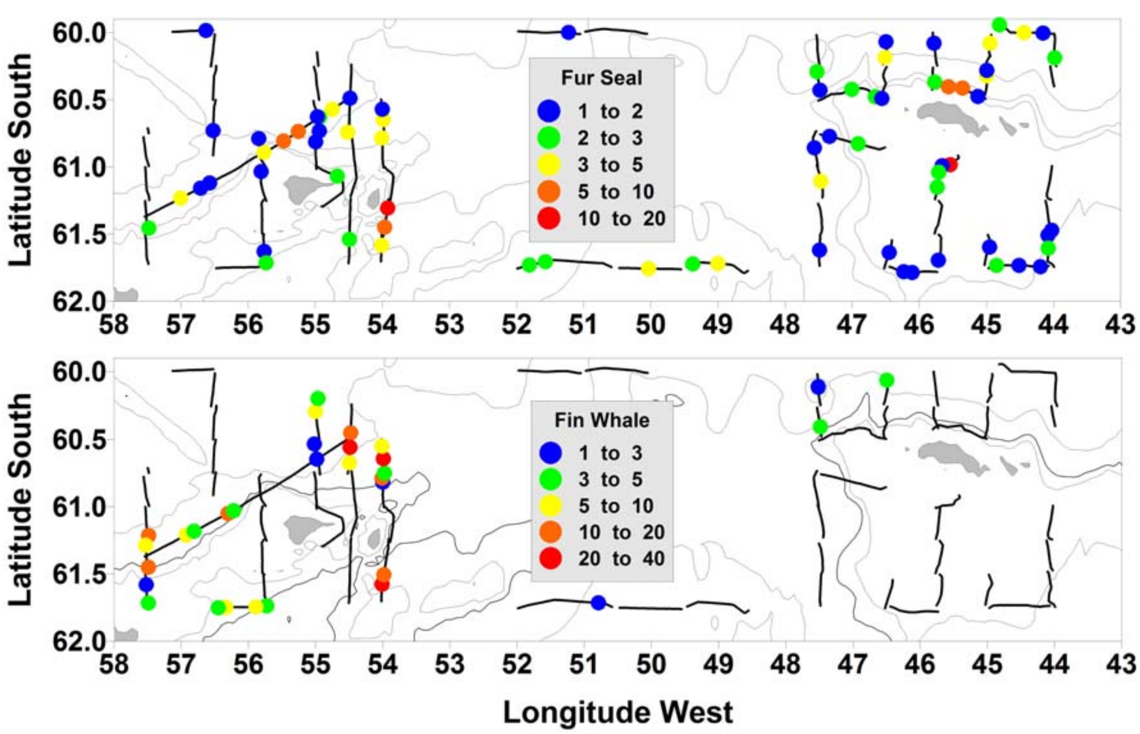


Figure 7.6. Distribution (#/10nmi) of (top) Black-browed Albatross and (bottom) Grey-headed Albatross during survey D AMLR08; (left) Elephant Island (right) South Orkney Islands.

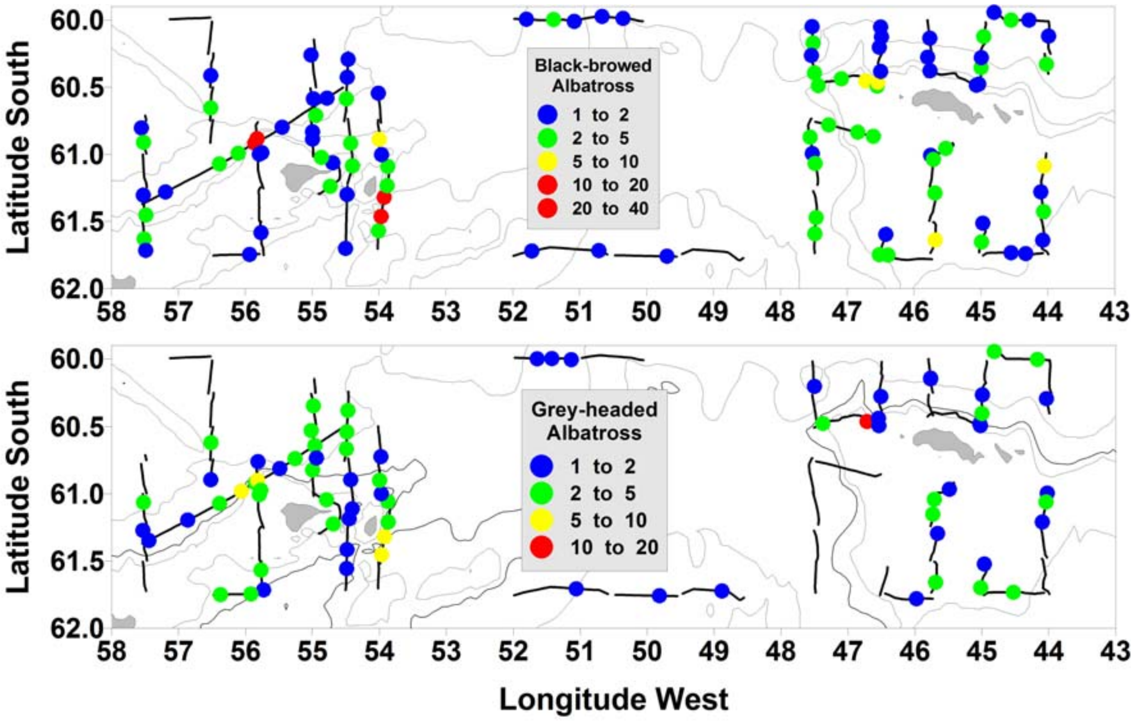


Figure 7.7. Distribution (#/10nmi) of (top) Chinstrap Penguin and (bottom) Prions during Leg II AMLR08; (left) Elephant Island (right) South Orkney Islands.

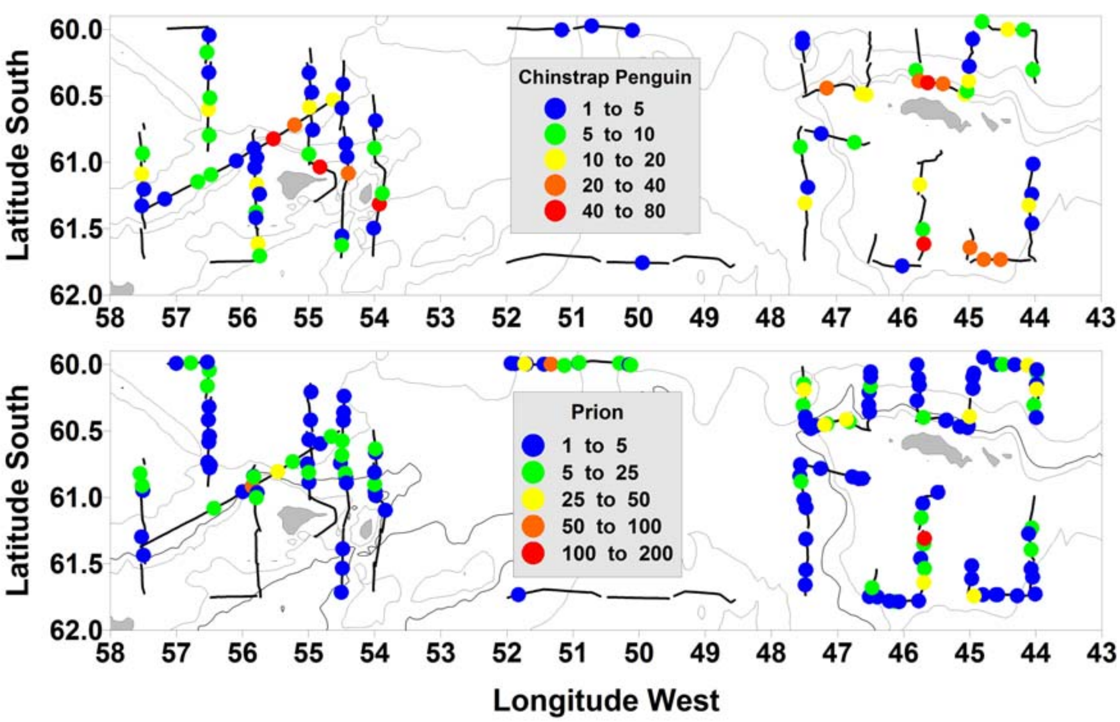


Figure 7.8. Distribution (#/10nmi) of (top) Antarctic Fur Seal and (bottom) Fin Whale during Leg II AMLR08; (left) Elephant Island (right) South Orkney Islands.

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